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Fuel Price Effects on Readiness

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Executive Summary

The Department of Defense (DoD) endured a series of sharp fuel price changes between 2005 and 2011, which resulted in a net $27 billion unbudgeted fuel requirement. Because most fuel used by the Department is used for operational purposes, the Office of the Secretary of Defense (OSD) is concerned that an unbudgeted fuel requirement may negatively impact operations and that this in turn may negatively impact readiness. In general, readiness refers to a Service's ability to produce units qualified and able to perform tasks and missions in time for emergent contingencies.

While fuel purchases represent only about 2.5 percent of the Department's budget, there is large variation among the Services. In Fiscal Year (FY) 2012, the year following the period we studied, fuel accounted for almost 16 percent of Air Force Operations and Maintenance (O&M) expenditures but only 4 percent of the Army's O&M and 1 percent of the Marine Corps' O&M. Also, since 2004, the rate of increase in the fraction of the O&M budget that is attributable to energy costs has accelerated, implying that as energy prices have increased, exposure to price risk has increased relative to other expenditures.

This research effort explored both qualitatively and quantitatively whether fuel price changes leading to an unfunded fuel requirement have affected readiness in the past, and whether they could again in the future. The qualitative component involved a series of interviews with the Services and review of doctrine and budgetary documents. This allowed the research team to develop a more nuanced view of how fuel price changes are handled.

The processes by which fuel is programmed for, budgeted for, acquired, and distributed shape the ways in which readiness can be affected by changes in price. The following list describes the basic Department-wide process:

- The Office of Management & Budget (OMB) projects the market price of crude oil.
- The Office of the Secretary of Defense (OSD) uses the OMB projection to project the price of refined petroleum products, and publishes official fuel rates.
- The Department sets requirements for refined petroleum products to support warfighter needs.

- DoD components program for fuel by multiplying their requirement by the OSD rate.[1]
- All fuel programming is wrapped up into a budget submitted to the president. The final programmed price is referred to as the President's Price.
- The DoD budget contains only enough funds to pay for programmed requirements at the budgeted price.
- Defense Logistics Agency (DLA) procures fuel on the world market to resell to the Services.
- The Defense Working Capital Fund (DWCF) finances fuel and uses available cash balances to attempt to stabilize customer prices relative to budgeted prices. (DLA charges all DoD customers anywhere in the world the same price per gallon.)
- When unable to stabilize the price at the budget price using cash balances, DLA adjusts the price charged to the Services.
- A DLA price increase results in an unbudgeted fuel requirement for the Services.

The DWCF can insulate the Services from fuel price volatility as long as it contains enough cash to absorb changes in market price. When its cash balance is insufficient, the impact of that volatility is passed on to the Services through fuel price increases, which results in an unbudgeted fuel requirement. Historically, the Congress has provided cash infusions to the DWCF to mitigate these price fluctuations. In 2006, the Congress stopped making cash infusions, and instead started providing supplemental funding directly to DoD. These supplementals, however, tended not to cover the full unbudgeted requirement. Furthermore, only contingency supplementals—covering the cost of fuel transportation to Afghanistan—have been provided since the end of FY 2010, leaving the Services to fund the fuel price increases themselves. The result has been a series of large unbudgeted requirements in all but two of the seven years from 2005 through 2011.

The quantitative analysis looked for quantifiable evidence that price volatility has caused changes in readiness. We estimated readiness using activity levels such as hours flown, miles driven, or days steamed for aircraft, vehicles, and ships, respectively. We gathered historical activity and fuel price data and employed regression analysis. To estimate the effect that changes in fuel prices have on readiness, we considered both the *long-term* effect (across budget years) and the *short-term* effect (within each budget year).

[1] The Air Force makes a minor adjustment to account for fuel purchased from other sources.

After analyzing fuel usage patterns across dozens of weapon systems and within Army, Navy, and Air Force operations, we did not find any meaningful empirical evidence that in-year changes in the DLA price relative to the budgeted price caused detrimental impacts to readiness. We arrived at this conclusion after failing to find any relationship between in-year fuel price changes and changes in planned fuel consumption, a finding that contradicts often-heard claims that volatility in fuel prices negatively impacts readiness.

This conclusion is consistent with the insights provided by interviews with relevant parties in the Services regarding their methods of dealing with unanticipated increases in fuel prices. It appears the Services will go to considerable lengths to ensure that readiness is not significantly affected by unbudgeted fuel shocks. These efforts range from requesting or reprogramming funds to altering operational decisions and procedures. Although the Services have thus far been able to ensure readiness in spite of fuel price increases, this paper discusses why DoD may find this increasingly difficult in the future.

Finally, we investigated the following question: given perfect hindsight, what funding scheme would have minimized disruptions? Using linear programming, we estimated that the best single-factor-adjustment policy DoD could have pursued was to have increased the President's Budget fuel price by 30 percent every year from 2005 to 2011. Such a policy would have resulted in a net unbudgeted requirement of only $2 billion dollars measured in FY 2013 dollars, instead of the $27 billion dollar shortfall that we actually observed.

Contents

1. Introduction

As the federal government's largest user of energy, the Department of Defense (DoD) uses approximately four-and-half billion gallons of petroleum-based fuel a year.[1] In 2013, the department budgeted more than $17 billion for fuel, which represents approximately 2.5 percent of the Department's overall budget, or a substantial 6 percent of the total operations and maintenance (O&M) budget.[2] Because the Department is such a large consumer of fuel, small increases in the price of fuel translate to large dollar increases. For example, an unbudgeted 1 percent increase in the price of fuel in 2013 would have meant an unplanned bill of $170 million, and a 10 percent increase would have meant a $1.7 billion bill. Since these bills would occur within the execution year, there would be no money in the budget to cover them. Even small price increases can therefore have a large impact.

The Department has historically attempted to insulate itself from potentially damaging market fluctuations by purchasing fuel through a working capital fund, which purchases fuel and then sells it back to the rest of the Department at a stabilized price. When the market volatility is relatively small, the pool of cash in the fund can be used to absorb market price increases, while being replenished by market price decreases. When volatility is great, however, the fund may have insufficient cash to absorb market price increases before being replenished. Prior to 2005, the Congress would infuse cash into the working capital fund whenever this happened, allowing the Services to pay the stabilized, budgeted price. Since 2006, however, the Congress has ceased supplementing the working capital fund to stabilize price, and in 2005, the Defense Logistics Agency (DLA), which manages the working capital fund, began changing the budgeted price in mid-year. Beginning in 2007, the O&M Overviews for the DLA-Energy (DLA-E) changed their language from implying that they always stabilize prices, to saying that they stabilize prices "most years," and since 2011, the Department has not received any supplemental funding from the Congress explicitly for fuel price increases. This means

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1 Moshe Schwartz, Katherine Blakeley, and Ronald O'Rourke, "Department of Defense Energy Initiatives: Background and Issues for Congress" (Washington, DC: Congressional Research Service, 2012), accessed May 1, 2013, http://www.fas.org/sgp/crs/natsec/R42558.pdf. It should be noted that as the largest federal consumer of energy, DoD accounts for 80 percent of the petroleum-based energy consumed by the federal government.

2 See DoD's "Report on Operational Energy Budget Certification for Fiscal Year 2013: Energy Investments for Military Operations," accessed May 1, 2013, http://energy.defense.gov/Portals/25 /Documents/Reports/20120815_FY13_OE_Budget_Cert_Report.pdf.

that in the past eight years, the Department has been less insulated from fuel price increases, and as a result, has experienced unfunded fuel requirements. In other words, the Department has found itself with fewer funds than necessary to purchase its programmed fuel.

Because fuel is funded primarily through DoD's O&M accounts, unexpected increases in fuel prices can lead to significant O&M funding shortfalls.[3] There is concern that these shortfalls could cause a degradation of the military readiness of our armed forces. Then Secretary of Defense Robert Gates gave voice to these concerns when he testified in 2011 that unbudgeted fuel costs could force cuts in Air Force flying hours, Navy steaming days, and training for home-stationed Army troops.[4]

The primary objective of this study is to determine the extent to which fuel price volatility has led to unfunded requirements that have, in turn, caused impacts to military readiness.[5] Specifically, Institute for Defense Analyses (IDA) was asked to present *empirical* evidence on whether fuel price volatility impacts military readiness. A corollary of this question is, if there is no evidence that fuel price volatility affects military readiness, then what does or does not happen when prices change? Have other O&M accounts, say, base operations, been tapped to pay for unanticipated increases in the fuel bill? Where possible we draw on firsthand accounts of what happens when fuel prices increase, to shed some light on higher order effects.

The remainder of this report is broken into five chapters. Chapter 2 defines readiness and explores the many ways in which it is conceptualized. In order to explore effects on readiness, it is important to have a solid understanding of what readiness is. Chapter 3 explores the processes through which fuel price could conceivably affect readiness and the mechanisms through which fuel price changes have been handled in the past. It also provides some insight about how they may be handled in the future. Chapter 4 presents the quantitative analysis from the research. This includes a general description of the data, overall trends in readiness measures, and tests of the effects of both long-term volatility and in-year price changes on several measures of readiness. The quantitative evidence suggests that there may have been some long-term response to market shifts in the Army, but there is no evidence that in-year volatility has had a negative impact on readiness. Chapter 5 concludes with some insights on possible future trends.

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[3] Schwartz, Blakeley, and O'Rourke, "Department of Defense Energy Initiatives."

[4] Ibid., 14.

[5] Lacking consistent cross-Service terminology, we have taken the liberty to use the term "unfunded requirement" rather loosely throughout this paper. Other terms include liability or shortfall for when the price goes above the budgeted price, and asset or surplus for when the price goes below the budget price.

2. Readiness

In order to understand any effects on readiness, we first must understand what readiness means. This chapter describes readiness as a concept, provides background into different ways to think about and measure readiness, and discusses the ways in which readiness may be affected by fuel.

In general, *readiness* refers to a Service's ability to produce units qualified and able to perform tasks and missions in time for emergent contingencies. Many different factors contribute to this ability. The Navy aptly categorizes these factors into five pillars, referred to as PESTO: Personnel, Equipping, Supply, Training, and Ordinance. These categories are useful for tying resourcing levels to readiness, but have varied applicability in this context.

Of these five pillars, Equipping, Supply, and Ordnance readiness all refer to different classes of supply,[6] and can be thought of as a single materiel readiness category. Equipping refers to Class VII supply, Ordnance refers to Class V, and Supply refers to all other classes. Equipment is relevant to readiness because units need functioning equipment to train and be prepared for contingencies, and because equipment is needed for units to accomplish their mission tasks. Supply and Ordnance are important to ensure the unit has the materiel required to train and supply it through the beginning of a conflict. The Service working capital funds are required to keep several days' worth of spare cash to fill any immediate requirements in the event of a contingency until additional funds become available to replenish spare part stocks. With the exception of items with a long production lead time, such as specialized repair parts, stocks can be replenished and limited amounts of equipment repaired more quickly than individuals and units can be trained.

Personnel refers to the presence of fit personnel to man the unit, while *training* refers to the preparedness of those personnel, individually and collectively, to perform the tasks in their Mission Essential Task List (METL).[7] If a unit is fully resourced in the Personnel pillar, it will have all, or close to all, of its authorized personnel, and sometimes more. Personnel is limited by Service end strength, and is funded out of the Military Personnel (MILPERS) accounts. It therefore has limited connection to fuel

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[6] The DoD categorizes supply into ten classes.

[7] The METL refers to those tasks that a unit may be called upon to perform in the event of a contingency.

prices, which mainly affect the O&M account. Training, on the other hand, is funded out of O&M and often requires fuel, and is therefore directly affected by fuel prices.

Training relates to all of the other pillars: there must be personnel to train, and training requires sufficient materiel readiness to be accomplished. Given reasonable manning and equipping levels, whether servicemembers and units are ready is determined by the degree to which they are trained and able to train in full spectrum operations. It is for this reason that factors related to the Training pillar were used as the primary quantitative measures of readiness in this paper.

Level of training can be measured using operating tempo (OPTEMPO), under the rationale that units that train and operate more will be better trained and more prepared for a contingency. OPTEMPO can, in turn, be measured either by resourcing—because additional operating and training will cost more—or by usage of systems that are considered pacing items for a given unit type. Pacing items are those whose usage correlates with how much a unit has been operating and training. Specific measures of OPTEMPO differ by unit type and Service.

In the Army, units at the highest readiness tier have generally completed more of their training. Most combat units progress through the Army Force Generation (ARFORGEN) cycle, which determines the unit's resourcing level, training schedule, and OPTEMPO. Units toward the end of the cycle have higher resourcing and OPTEMPO, and thus, higher readiness levels. Relative OPTEMPO can thus be measured through the unit resourcing level, or by usage of pacing items specific to the unit type. Usage of pacing items can be measured in either miles driven by ground vehicles, or hours flown in aircraft. For example, a Stryker Brigade Combat Team (SBCT)'s OPTEMPO might be approximated using Stryker miles, while a Heavy Brigade Combat Team (HBCT)'s pacing item might be a tank with OPTEMPO measured by tank miles. Different pacing items can also be chosen for units of different echelons. For example, a Heavy Combat Aviation Brigade (CAB)'s pacing item might be an Apache, while the Assault Helicopter Battalion (AHB) within it might use Black Hawks, with usage measured by flying hours in both cases.

Miles and hours are a rough approximation of activity. They do not directly account for training in simulators, individual training, or training not requiring much vehicle use. They are an appropriate measure of overall training as long as the proportion of unit training involving vehicles remains constant. While there is no way to determine whether, on one hand, any reductions in miles were replaced with simulator training, or on the other hand, other training activities were sacrificed for hours and miles, we believe that

miles and hours still represent the best available measure of OPTEMPO and Training Readiness.[8]

In the Air Force and Naval Air Force, OPTEMPO is measured in flying hours. Neither the Air Force nor the Navy uses tiered readiness for their flying units, meaning that they both must be prepared to deploy a large proportion of their forces within seventy-two hours, and the rest shortly thereafter. All pilots and crews must therefore be highly trained at all times. In the Air Force, pilots are rated combat mission ready (CMR) or basic mission capable (BMC). A given unit will have a mix of pilots flying at the CMR and BMC rates. To maintain certification at a given rate, crews must fly the required number and type of sorties per month, averaged within a three-month period. For example, a CMR crew for a given aircraft type might fly, on average, eight sorties a month, with seven one month and nine the next, while a BMC crew for the same aircraft type might fly, on average, six. The BMC rate is considered the minimum amount of flying required in order for a pilot to be safe to continue to fly an aircraft, but is considered too low for the pilot to be ready to engage in high intensity combat. Those at BMC are often able to reach CMR status quickly if needed, or to engage in lower intensity missions in the event of a contingency. If a pilot does not fly enough sorties over a three-month period to average their given qualification rate, they are put on probation. CMR pilots on probation are still considered CMR unless they continue not to fly the required number of sorties. This is relevant because under resource constraints, units can reduce the number of sorties flown by using probation status strategically. Such strategic usage might not be evident either in the data, or to higher echelon observers, but is likely to only cause minimal impact to readiness.

The amount of time pilots fly is not a perfect measure of readiness, because not all hours produce the same amount of training.[9] Flying operational hours in a non-challenging environment may give the pilot a large number of hours without preparing the pilot for full-spectrum operations. For example, deployed pilots often cannot complete full-spectrum currency training, meaning that full-spectrum readiness often suffers during deployment. On the whole, however, more flying generally coincides with more training, and flying hours are the best and most commonly used approximation for readiness. In addition to flying hours, and flying hours compared to planned hours, we also looked at aircraft equipment readiness by observing the number of mission capable aircraft.

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[8] In the Army, simulators are run by contractors at a fixed annual cost, and there is little visibility into relative usage over time.

[9] A3 (Air Force Operations Plans and Requirements) has a ranking system that they apply to different types of hours. More challenging hours use greater resources, and also produce more training.

Surface Navy pacing items are ships, which can be in one of three states: cold iron, steaming underway, and steaming not-underway. Underway steaming is equivalent to hours and miles in that it indicates the time during which a ship was moving. Not-underway steaming refers to times when the ship is operating under its own power, but is not moving. Not-underway steaming generally has a burn rate, as measured in gallons of fuel used per day, of about one fifth that of underway steaming. Cold iron refers to times when a ship is turned off or is plugged into port energy sources, during which it uses no fuel.

The relationship between readiness and OPTEMPO in the surface Navy is a bit more complicated than in the other Services. OPTEMPO can be measured by resourcing or by activity. Resourcing and activity data can be captured by looking at fuel consumption, but consumption is not as good a proxy for ship OPTEMPO as it is in ground vehicles or aircraft. Different missions result in vastly different fuel burn rates, even among ships of the same type. This is due to differing requirements regarding ship speed and engine configuration, so more gallons consumed does not necessarily equate to more or better training. For example, a ship chasing a carrier is required to have all engines on, and in a configuration that consumes maximum fuel, no matter what speed the carrier group is traveling. Another ship, either in training or on another mission, might perform similar tasks with similar maneuvers and speeds, while consuming far fewer resources, because its engine configuration can be optimized. Time steaming underway is also an imperfect measure of training because training is conducted under all three states: steaming underway, steaming not-underway, and cold iron. Time underway may give the crew additional preparation in operating the ship, but it also may reduce the amount of not-underway training they receive. However, time underway is still an appropriate measure of readiness, because it has been positively linked with increased training readiness and materiel readiness,[10] and was therefore used as our primary measure of ship OPTEMPO. A measure of gallons consumed was also included for comparison.

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[10] Thomas D. Nolen, "Isolation of Important Input Factors in the Performance of Operational Propulsion Plant Exams (OPPE) and Light Off Exams (LOE) for Atlantic Fleet Ships" (Monterey, CA: Naval Post Graduate School, 1989), http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier =ADA219807; Lawrence Goldberg, "Estimation of the Effects of A Ship's Steaming on The Failure Rate of its Equipment: An Application of Econometric Analysis," Professional Paper PP-280 (Alexandria, VA: Center for Naval Analyses, 1980), http://www.cna.org/sites/default/files/research /5500028000.pdf; and GAO report 12-887, "Military Readiness: Navy Needs to Assess Risks to Its Strategy to Improve Ship Readiness" (Washington, DC: Government Accountability Office, 2012), http://www.gao.gov/products/GAO-12-887. Nolen finds that time underway predicts increased training readiness. Goldberg finds that increased steaming predicts decreases in equipment casualties. This finding may require that ships receive sufficient materiel resourcing so they can make underway repairs, and may depend on the preparation of sailors to make underway repairs. The effect of training on materiel readiness was reviewed by GAO report 12-887.

Unfortunately, materiel, personnel, and training readiness are also less directly captured by usage of pacing items in the Navy than in other Services. Contrast ships with aircraft. Unlike an aircraft, a ship can continue to steam and even carry out most of its tasks and missions with compromised materiel readiness. Compromised readiness could, however, cause casualties and reduce the range of potential operations for which the ship is ready. Similarly, a ship can steam with less than its full complement of personnel, and without those personnel being fully trained on all onboard systems. However, given fewer personnel with less training, the crew can accomplish less. For example, after the ship crew efficiency reductions in the 2000s, crews on destroyers only had the personnel to man a single replenishment station during underway replenishment; before that time, they had been able to man two.[11] This meant that the ship had to remain in a dangerous side-by-side configuration with the resupply ship for twice as long. Materiel and personnel readiness have both been an area of recent concern for the Navy and the Congress. A recent GAO report outlines the Navy's efforts to resolve the problem.[12]

The new surface Navy readiness plan is intended to resolve many of these readiness issues. It follows a cycle similar to ARFORGEN, which regulates inspections and training. The cycle begins with a deployed or ready ship, which continues readiness sustainment training. The ship then undergoes maintenance and crew rotations, individual training of seamen on their system, and training at increasingly higher levels of organization until units are fully ready within their battle group. Under the new plan, inspections are more detailed and occur more often. This renewed focus on readiness may help to limit readiness impacts, whether from fuel price changes or other factors, in the future.

No available measure perfectly describes readiness in any of the Services. The quality and nature of training vary, and OPTEMPO does not always directly capture all of the pillars of readiness. For example, if too many aircraft are in disrepair, no amount of pilot and crew training will enable the Air Force to project them if they are needed. When measuring OPTEMPO with miles, flying hours, or steaming, OPTEMPO only indirectly captures equipment readiness. On the other hand, units require working equipment to train, so units with high OPTEMPO likely have more funding and are likely to have high equipment readiness. On the whole, more activity means more readiness, and we therefore chose OPTEMPO as an appropriate measure.

There are many other factors that contribute to readiness indirectly. Investments, for example, contribute to future readiness. Investment does not, however, directly impact

[11] GAO report 10-592, "Military Readiness, The Navy Needs to Reassess Its Metrics and Assumptions for Ship Crewing Requirements and Training" (Washington, DC: Government Accountability Office, 2010).

[12] GAO report 12-887, "Navy Needs to Assess Risks."

the ability of the Services to project forces in the short term, and is therefore not considered part of readiness.[13] Facilities and construction likewise may contribute to the ability of the Services to make units ready, but do not directly impact the readiness of units in the short term.

[13] There are exceptions to the impact of investment on readiness. For example, the development of the Mine Resistant Ambush Protected (MRAP) vehicles was a combat imperative.

3. Qualitative Assessment: Processes and Trends

The processes by which fuel is programmed for, budgeted for, acquired, and disbursed shape the ways in which it can impact readiness. We explored these processes through a systematic series of interviews with representatives from offices involved in fuel-related processes at multiple echelons, as well as through review of official doctrine, budget materials, and other studies on fuel. (See Appendix B for a list of interviewed offices.) This chapter will describe these processes and the mechanisms by which they can conceivably affect readiness. It might be helpful to keep in mind some basic facts surrounding the process through which DoD programs for and purchases fuel, as one reads this report. The following list outlines the basic process:

- Crude oil is traded by the 42-gallon barrel on the world market.
- The Office of Management and Budget (OMB) projects the market price of crude oil approximately two years in advance.
- The Office of the Secretary of Defense (OSD) uses the OMB crude oil price projection to project the price of refined petroleum products, and publishes official fuel rates.
- The Department sets requirements for refined petroleum products to support warfighter needs.
- DoD components program for fuel by multiplying their requirement by the OSD rate.[14]
- All fuel programming is wrapped up into a budget submitted to the president. The final programmed price is referred to as the President's Price.
- The DoD budget contains only enough funds to pay for programmed requirements at the budgeted price.
- DLA procures fuel on the world market to resell to the Services.
- The Defense Working Capital Fund (DWCF) finances fuel and attempts to stabilize customer prices with available cash balances.
- DLA charges all DoD customers the same price per gallon, worldwide.

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[14] The Air Force makes a minor adjustment to account for fuel purchased from other sources.

- When unable to stabilize the price at the budget price using cash balances, DLA adjusts the price charged to the Services.
- A DLA price increase results in an unbudgeted fuel requirement for the Services.

How the Services handle these unbudgeted requirements determines how fuel prices could conceivably affect readiness. Subsection A provides some background on DLA and describes how it procures and prices fuel to sell to the Services. It also explores how recent market volatility has affected DLA and the Department as a whole. Subsection B uses information collected from Service interviews and doctrine in order to describe the Departmental processes associated with fuel, and to explore the ways in which fuel price changes have affected the Services and might continue to do so in the future.

A. Department-Wide Fuel Management

1. DLA's Role

DLA-E has the mission of acquiring, storing, selling, and distributing energy including petroleum, natural gas, and coal for all DoD Services and agencies both in the continental United States (CONUS) and outside the continental United States (OCONUS).[15] DLA-E is always in the market for a heterogeneous basket of refined energy products. It uses the DWCF to buy from suppliers around the world and resell to customers within DoD, acting as a clearinghouse for supplying DoD's petroleum needs.[16] About 71 percent of DoD's energy comes from refined petroleum-based liquids.[17] Since petroleum-based liquids constitute the overwhelming majority of the fuel consumed by DoD customers, this paper focuses on those types of energy.[18] See Appendix C for more details on the types of fuel purchased by DLA.

As the energy clearinghouse, DLA-E is exposed to market volatility. The Department does not have storage capacity to hold a year's worth of fuel purchased in advance, so fuel is purchased throughout the execution year. Fuel is generally purchased

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[15] See DLA-E's mission statement at http://www.energy.dla.mil/about_energy/Pages/Mission.aspx.

[16] Schwartz, Blakely, and O'Rourke, "Department of Defense Energy Initiatives."

[17] Nuclear-fueled ships account for 7 percent of DoD's operational energy, and installations also use energy in the form of electricity (11 percent), natural gas (8 percent), and coal (2 percent). See Schwartz, Blakely, and O'Rourke, "Department of Defense Energy Initiatives," 5, for a more detailed categorization of fuel, and definitions of operational and non-operational fuel. Refined liquids include fuel products such as gasoline, Diesel, aviation fuel, and fuel oil.

[18] Defense Working Capital Fund, Department of Defense Study on Revolving Funds Operational Cash Balances, Report to the House Armed Services Committee (Washington, DC: January 2012), 41. We have also excluded liquefied propane gas (LPG), from this study.

through four IDIQ (Indefinite Delivery/Indefinite Quantity) fixed price annual contracts with economic adjustments,[19] through which DLA pays the market price for fuel at whatever time it is purchased.[20]

DLA-E uses the DWCF to try to insulate the rest of the Department from market volatility. DLA-E uses the cash reserve in the DWCF to absorb market price changes—using the cash reserve to cover the difference when the price increases, and replenishing the reserve when the price decreases. The Services depend on this stabilized price because they are on a fixed budget, and any increase in fuel price from the budgeted price would mean that they cannot purchase their full budgeted requirement with only the funds that had been budgeted specifically for fuel. They would either have to purchase less fuel, receive supplemental funding, or use funds that had originally been budgeted for something else.

Prior to 2005, whenever there was insufficient cash in the DWCF to absorb market volatility, the Congress would generally make a cash infusion into the fund in order to stabilize the budget price. Since 2006, Congress has ceased making these cash infusions, and market volatility that exceeds the DWCF's capacity to absorb has been passed on to the Services.[21] Furthermore, about 75 percent of DoD's energy use is for operational purposes; and only 25 percent is used at installations or for non-tactical vehicles. This suggests that market volatility has the potential to affect Service operational activity, and thus readiness.

The DLA-E sets a global price for each type of fuel (e.g., JP-8, Diesel, or gasoline). This price is computed by averaging the worldwide crude oil cost of anticipated fuel purchases and adding a refinement cost and operating surcharge to cover worldwide operating expenses (i.e., storage and distribution).[22] Table 1 shows the components that

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19 The four annual contracts are known by their geographical areas: Atlantic Europe Mediterranean; Rocky Mountain and West Coast; Western Pacific; and Inland and Gulf Coast.

20 Anthony Andrews, "Department of Defense Fuel Spending, Supply, Acquisition, and Policy," (Congressional Research Service, September 22, 2009), 1. Also, "Re-examining Best Practices for the Department's DoD Fuel Acquisition," Report to the Defense Business Board, January 7, 2011. This study, which was commissioned by the Defense Business Board, notes that this strategy is at variance with many other large fuel users. The focus of the study was on the use of various fuel-hedging strategies employed in the private sector that might inform DoD's efforts to reduce the Department's exposure to fuel price volatility. The researchers recommended DLA consider implementing some changes to the contractual arrangements, but that DoD not use hedging techniques that involve financial instruments.

21 2005 saw a small cash infusion that did not completely stabilize price.

22 Here, worldwide cost refers to the cost at the time and place at which it was purchased. DLA-E generally purchases fuel from sources close to where it is needed in order to reduce transportation costs. This means that rather than purchasing fuel at the lowest cost per gallon, DLA-E purchases fuel at the lowest cost to get that gallon to the point of delivery. See Schwartz, Blakely, and O'Rourke,

go into the standard per-barrel price build-up. These data are from the FY 2013 President's Budget (PB).

Table 1. Standard Price Build-up per Barrel (FY 2013)

Component	Price/Barrel
Crude Oil	$93.28
Refining	$46.64
Product Loss	$2.20
Transportation	$3.21
FSRM*	$3.70
Operations	$4.07
Rounding	$0.12
Total	$156.66

* FSRM stands for Facilities Sustainment, Restoration, and Modernization.

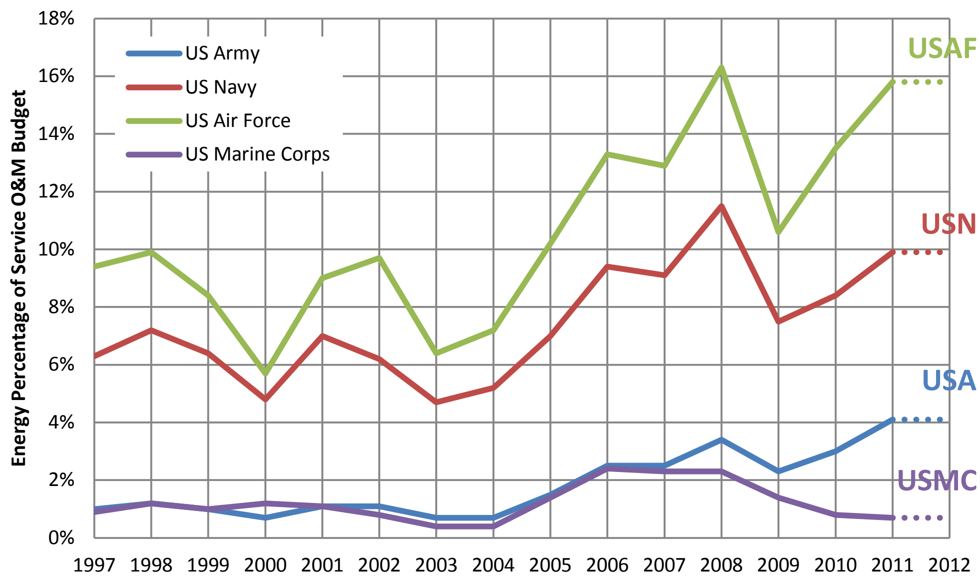
Under this system, DLA-E charges a DoD customer in Kuwait the same for a barrel of fuel as it does a customer in CONUS.[23]

2. Price Changes, Cash Infusions, and Supplemental Funding

Fuel purchases represent approximately 2.5 percent of the Department's budget. Among the Services, however, the size of their fuel bill relative to their total budget varies widely. Figure 1 shows energy costs as a percentage of O&M for each of the Services. This observation suggests that the relative size of the fuel bill may play a role in how the Services respond to fluctuations in fuel prices. We also observe that energy costs have been growing since the beginning of the 2000s, both as a proportion of O&M, and in absolute terms, even though fuel quantities purchased have remained relatively stable, as demonstrated by Figure 2.

"Department of Defense Energy Initiatives," 5. For more on the Standard Price Build-up, see Schwartz, Blakely, and O'Rourke, 6.

23 Note, the DWCF also receives an appropriation to offset the cost of fuel delivery to Afghanistan and Iraq so that the Services do not bear Overseas Contingency Operations (OCO)-related costs when purchasing fuel from their base budgets.



Source: DLA Energy Fact Books (FY 1999–FY 2011) and annual PB (FY 1998–FY 2013).

Figure 1. Percentage of Service Budgets Used for Liquid Petroleum Fuels

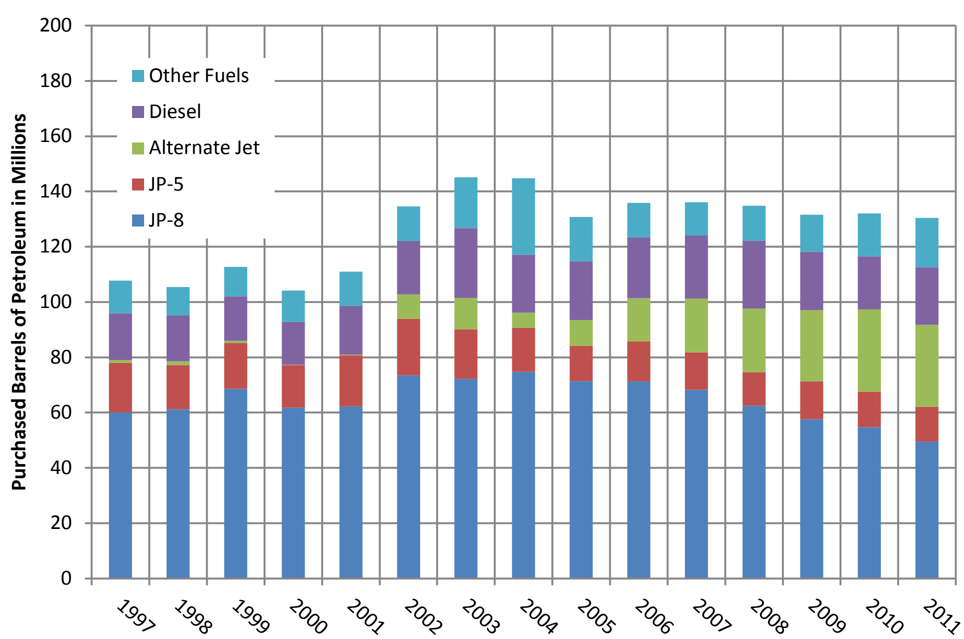


Figure 2. DLA-E Energy Fuel Products Purchased by Category

On one hand, Figure 2 appears to show that fuel purchases have not decreased significantly since 2005, which suggests that fuel was purchased in spite of price increases, and that operational activity may not have been affected. On the other hand, the observations in Figure 1 imply that as energy prices have increased, exposure to risk has increased relative to other O&M expenditures—a price increase affects a much larger percent of O&M than it used to, making it all the harder for the O&M account to absorb

price changes. Several interviewees expressed concern that fuel expenditures have an adverse impact on other O&M programs. The funds to purchase the fuel had to come from somewhere, but that source of funds was probably not OPTEMPO O&M funds.

There has been a series of sharp fuel price changes beginning around 2004–2005.[24] To get a sense of this history, Figure 3 compares the changes in price for West Texas Intermediate (WTI) Crude, the benchmark price for crude oil in America, to changes in the spot prices for jet fuel, the major refined component of DoD purchases. The year-to-year prices were normalized to FY 2013 dollars before being converted to percentage changes. The x-axis refers to fiscal years. The 2000s have seen relatively high price volatility.

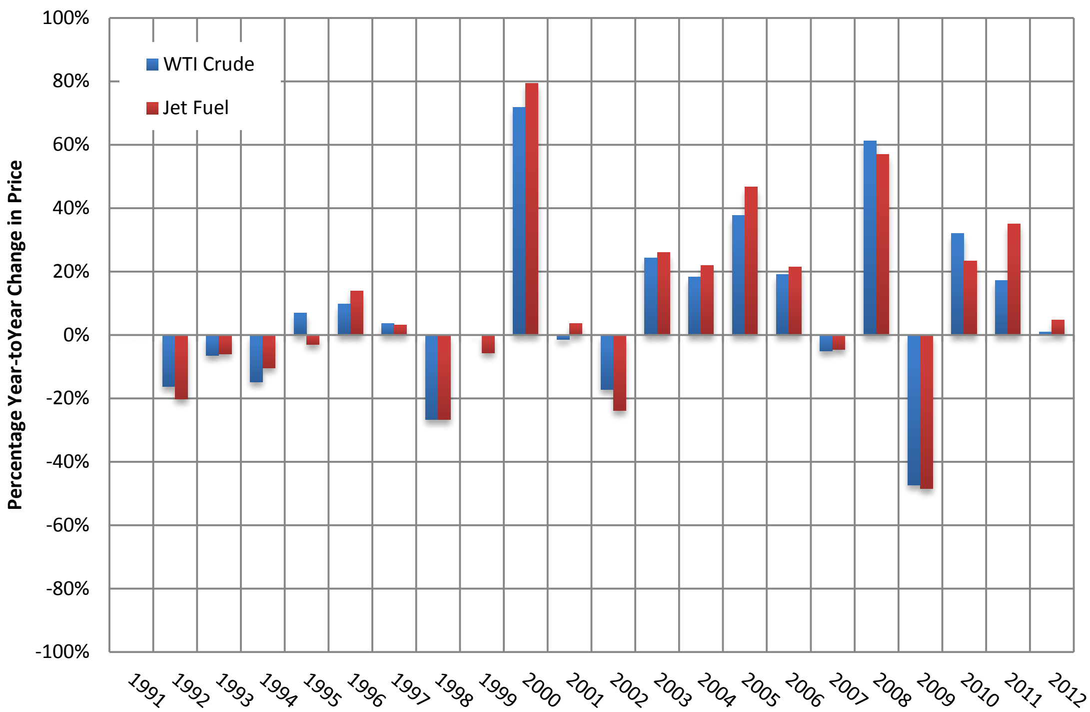


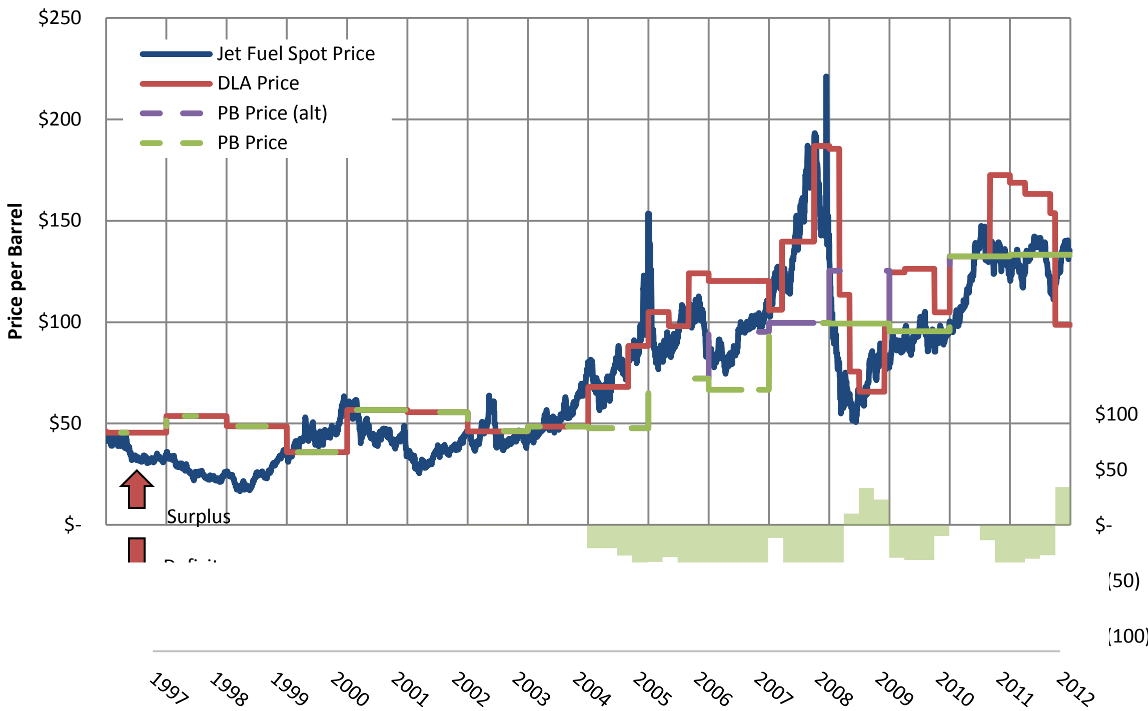
Figure 3. Percentage Year-to-Year Changes in WTI Crude and Spot Market Jet Fuel Prices

This recent price volatility has created a problem for DoD. The budgeted price of fuel, used for all DoD planning, is established in February of the year prior to the budget-year, using the OMB forecast of the crude price at the time. If the price volatility is high, the projected price is less accurate, and there is a greater chance that the DWCF will be unable to stabilize the price. As shown in Figure 4, not only has the price been volatile, but it has been increasing, meaning that most years the estimate has been too low.

24 In absolute terms, the series of price adjustments beginning in 2004–2005 had a larger effect than the single spike in 2000.

Without congressional cash infusions, this has meant that DoD components have often been paying more than the budgeted price.

Not only did volatility increase, but price has increased dramatically in the past decade. Figure 4 illustrates how the standard DLA price has diverged over time from the price printed in the PB. The y-axis represents the standard price per barrel measured in FY 2013 dollars. The x-axis represents fiscal years (denominated in quarters) from 2001 through 2011. Starting in the final quarter of FY 2004, after the disruption of refinery operations from Hurricane Katrina, fuel prices began a period of volatility that peaked in 2008–2009 and continues on to the present time.



Note: Presented in $FY13. Fuel price changes have generated unbudgeted requirements of $25 billion since the beginning of FY 2005. Note that the surplus/deficit measure ignores the effects of OSD price change mitigation activity as well as any supplemental or cancelled funding received by the Services. See Figure 5 for funding context.

Sources: U.S. Energy Information Agency (EIA), PB, OSD Comptroller, Standard Price Memorandums.

Figure 4. Year-to-Year Changes in the DLA Price and the President's Budget Price

There are two obvious things to note about this difference measure. One is the size of the difference; in FY 2008, it approached $100 per barrel! The other notable feature is the asymmetry of the difference. Except for three quarters in 2009 and one quarter in 2013, all the variance is in the direction of a liability (i.e., the DLA price is greater than the PB price) rather than toward an asset (i.e., the DLA price is less than the PB price). DoD would much rather deal with an asset than a liability, since the latter implies either that additional money for fuel will need to come from elsewhere in the budget or that the

use of fuel will have to be curtailed. Because the price difference has usually resulted in a liability, and because assets are not threatening to readiness, the remainder of this report will focus on unbudgeted requirements due to fuel price fluctuations.[25]

So far we have discussed fuel price in isolation. Figure 5 puts the price changes into context. The values and explanations gathered in this figure come from the DLA-E O&M Overviews for the relevant budget year. The top row of numbers for each fiscal year in Figure 5 lists the PB price, adjusted for inflation. (Colors are used to denote boxes that all pertain to the same fiscal year.) This top figure represents what the Services planned to pay, and is the value against which DLA prices and price changes were measured. The values in this table represent the values cited in the O&M Overviews for the relevant budget year. For example, the FY 2006 price is taken from the FY 2006 O&M Overview, because it represents the projected price, not the actual price paid. The Overviews are published close to, but still prior to the submission of the PB, so the price listed is likely, but not necessarily, the final PB price at the time that the president submitted the budget to the Congress. Data on the PB price provided by the OSD Comptroller sometimes differed from the O&M Overview data. Specifically, the PB price in the Comptroller data for FY 2007 was recorded as $67 instead of $95, and the PB price in FY 2009 was recorded as $99 instead of $125. We labeled that line “PB Price (alt)” on the composite graph in Figure 4. Note that all quantitative results remained the same regardless of which data set was used. For consistency, the Overview prices are listed in Figure 5.

The boxes below the PB price on the top half of the timeline represent the prices that DLA charged DoD customers. The DLA price was revised at least once each year from 2005 through 2012, and in some years the price was revised three or four times. Minus signs above the price box represent prices that were higher than the budgeted price, and plus signs represent prices that were lower, referring to whether they caused a deficit or surplus for the Services. Only in 2009 did the Services end the year with a surplus. The only other year the DLA price was revised downward was 2012, but since this was after it had already been revised upward, the net effect was a deficit for the year.

The lower half of the timeline shows relevant events that provide context to the price changes. A few trends stand out. First, small supplementals were provided from the Congress to the DWCF every year from 2002 onward to provide additional funds for the added cost of transporting fuel to theater. Second, prior to 2005, the Congress tended to infuse money into the DWCF to stabilize prices. Around 2005 this ceased, and from 2007

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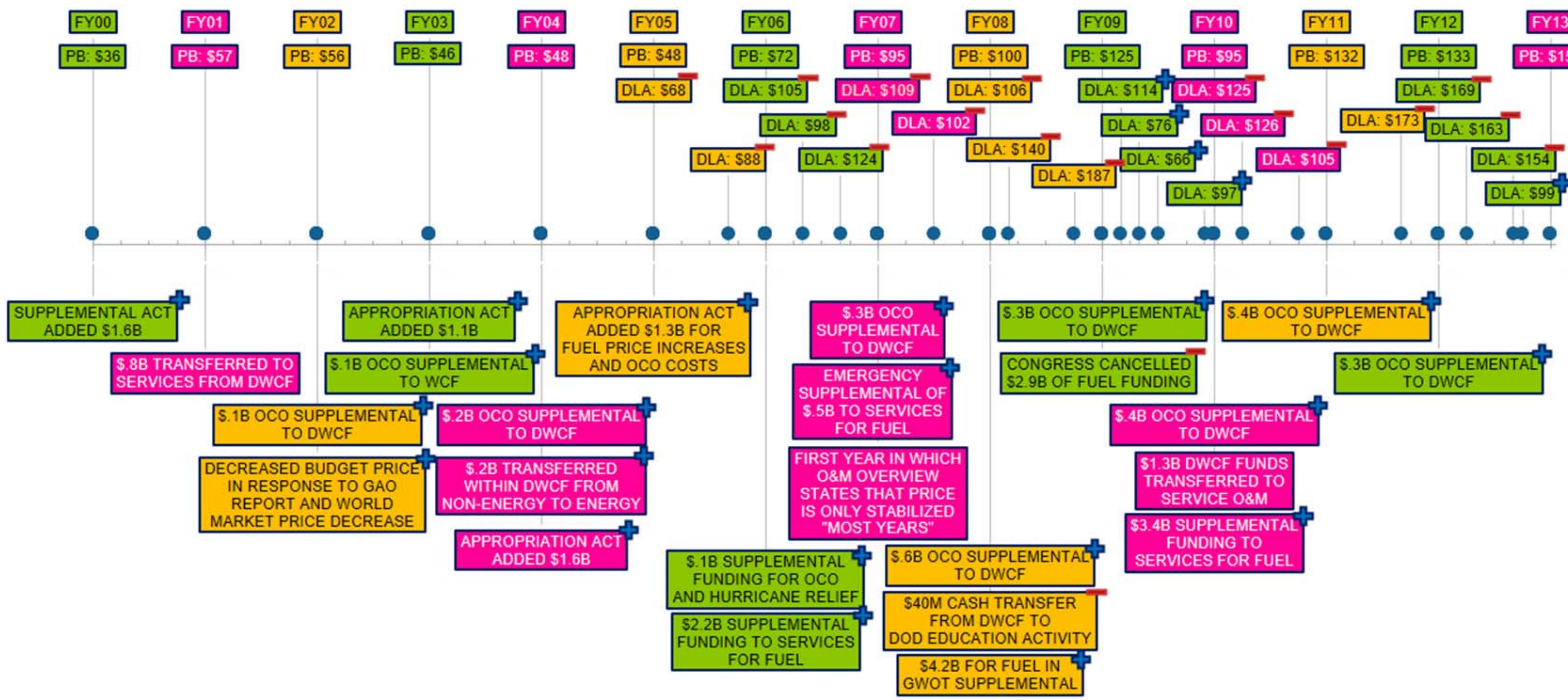
[25] We have chosen the President’s Budget price as the baseline from which to measure change. One could also make a case that we should use the price as appropriated, since it is conceivable that there may have been occasions when volatility forced DoD to adjust the standard price after the President’s Budget was submitted in February but before the budget was actually appropriated at the beginning of the fiscal year. We believe using the President’s Budget price as a baseline best represents the decision making process we are trying to capture.

onward, the O&M Overview changed its description to specify that DLA only stabilized fuel prices in “most years.” After 2005, but before 2011, the Congress tended to supplement the Services themselves in order to enable them to pay for the increased fuel prices, rather than stabilizing the prices through the DWCF. Often the supplemental fuel funds came through the OCO supplemental budgets, because training in preparation for combat could be funded out of OCO. OCO demands also reduced the availability of units to train. In combination, supplemental funding and reduced unit availability likely enabled the Services to mediate the effect of increased fuel prices on OPTEMPO, and thus on readiness.

Also of note, in 2009, when fuel prices decreased, the Congress removed excess funds, but returned those funds in 2010 when the price increased. Finally, in 2011 and 2012, fuel prices increased again, but additional funds were not provided, either directly to the DWCF or the Services.

Even though the Services usually received supplemental funding to help mitigate fuel price increases, the supplemental funding tended not to cover the full unbudgeted requirement. Yet, at the same time, results from the regressions suggest that activity did not decrease due to fuel price increases. There were also no drops in the number of barrels purchased from DLA, and the Service representatives we spoke to suggested that they had never reduced OPTEMPO due to fuel prices. This is likely because reprogramming was able to cover the gap that supplemental funds did not cover, and because requirements tend to change over the course of the year. Although the requirement reflects the Services’ ideal consumption, real life events often prevent training, impede operational activity, or alter schedules in ways that can reduce the requirement over the course of the year.



Note: The top half of the timeline shows historical fuel prices. The PB price is listed on top, and all DLA price changes for each year are listed below, at the point at which they occurred on the timeline. In the top half, minus signs in the top right corner signify unfunded requirements, and mean that the price went above the PB price; plus signs signify a surplus of funds due to the price dropping below the PB price. The bottom half of the timeline shows contextual information such as cash infusions and supplemental funding. In the bottom half, a plus sign indicates cash being added to the DLA-E working capital fund, or given to the Services directly from the Congress; a minus indicates funds being taken away from DLA-E to be used for non-energy purposes.

Figure 5. Timeline of Fuel Funding

3. Unbudgeted Requirement *Post Hoc* Analysis

We define the unbudgeted requirement caused by fuel price fluctuations to be the difference between what DoD expected to pay for fuel and what it actually paid, multiplied by the amount of fuel that was consumed. We calculated this for the period from FY 2001 to FY 2011 when the DLA price differed, sometimes substantially, from the PB price. Operationally, the dollar amount of the unbudgeted requirement is computed as:

$$Unbudgeted\ Req. = \sum_{2001}^{2011}(P_{DLA} - P_B) \times F, \tag{1}$$

where P_{DLA} is the average standard price per barrel over the fiscal year, weighted by the amount of time that price was in effect. P_B is the PB price per barrel, and F is the total barrels of fuel used in the fiscal year. The first five columns of Table 2 present the calculation of the dollar value of unbudgeted requirements from FY 2001 through FY 2011. This method suggests that the unbudgeted requirement total is about $27 billion dollars, measured in constant FY 2013 dollars.

One could argue that the obvious solution to mitigating the volatility is better forecasting of the future fuel prices. It turns out this is easier said than done. A recent Federal Reserve Board paper examined a number of forecasting models over periods of one month, three months, six months, nine months, and twelve months in the future and found that "a forecaster using the most recent spot price would have done just as well in forecasting the nominal price of oil." The Board's study also notes that, "at the 1 month and 3 month horizon, the success ratio of the futures price forecast actually is inferior to tossing a coin."[26] The difficulty in predicting the future price of fuel is analogous to playing the futures market in fuel. In an efficient market, we should not expect to profit from such a strategy over the long term. A DoD report to the Congress in 2007 reviewed alternative projection measures and found that using the OMB-projected price was among the best of many poor alternatives.[27]

While we may not be able to predict future fuel prices, an interesting excursion is to ask, given perfect hindsight, what DoD's best policy to pursue over the FY 2005–FY 2011 period (when unfunded requirements were generated) would have been if its sole objective was to incur nether a deficit nor a surplus. Or, put another way, what single-factor adjustment to the PB price (P_B) would result in the smallest absolute deviation in DLA prices and the PB prices?

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[26] Ron Alquist, Lutz Kilian, and Robert J. Vigfusson, "Forecasting the Price of Oil," *Handbook of Economic Forecasting* 2A (2013): 427–507, accessed January 7, 2014, doi: 10.1016/B978-0-444-53683-9.00008-6.

[27] The congressional report is reviewed in GAO report GAO-07-688R.

In algebraic terms, the “optimal” unfunded requirement calculation can be expressed as:

$$Optimal\ Unfunded\ Req. = \sum_{2005}^{2011} |P_{DLA} - \delta P_B|, \qquad (2)$$

where δ is the policy adjustment factor and all other symbols retain their previous meaning. Using linear programming, we estimated $\delta = 1.30$.[28] That is, the best policy DoD could have pursued was to take the PB price and increase it by 30 percent every year from FY 2005 to FY 2011. This would have resulted in a total unfunded requirement of about \$2 billion dollars (deficit) in constant FY 2013 dollars terms. The last two columns of Table 2 show what the optimized unfunded requirement would have been if the PB price had been increased by 30 percent during the most volatile years. Of course this computation is only possible after the fact, but it gives the reader a sense of the magnitude of the budget chaos as a result of the wild fuel price swings over the past decade. See Appendix D for more details about the analysis.

Table 2. DoD’s Unfunded Requirement for Fuel, FY 2001–FY 2011, and *Post-hoc* Analysis (in \$FY13)

	Actual Prices and Unfunded Requirements				Post-hoc Analysis	
Fiscal Year	**Total Barrels in Millions (F)**	**P_{DLA} per Barrel**	**P_B per Barrel**	**Unfunded Budgeted $(P_{DLA} - P_B) \times F$**	**$1.3P_B$ per Barrel**	**Unfunded Requirements $(P_{DLA} - 1.3P_B) \times F$**
2001	111.0	\$ 57	\$ 57	\$ 0		
2002	134.6	56	56	0		
2003	145.1	46	46	0		
2004	144.8	48	48	0		
2005	130.7	75	48	3,529	\$ 63	\$1,624
2006	135.9	109	72	5,028	94	2,057
2007	136.1	120	67	7,213	87	4,445
2008	134.9	144	100	5,936	130	1,840
2009	131.6	98	99	−132	129	−4,087
2010	132.0	120	95	3,300	124	−508
2011	130.5	146	132	1,827	172	−3,403
				\$26,702 M		**\$1,967 M**

Note. All dollars are reported in \$FY13. Post-hoc analysis performed by increasing P_B by 30 percent in each fiscal year from 2005 to 2011 (derivation described in Appendix D). Congressional supplements are not included in this analysis.

[28] Appendix D details the linear programming formulation and computations.

4. Conclusions

The way in which DLA purchases fuel exposes it to risk from fuel price volatility. The DWCF can insulate the Services from volatility as long as it contains enough cash to absorb changes in market price. When it does not have a sufficiently large cash balance, the impact of that volatility is passed on to the Services and results in an unfunded fuel requirement. Since the early 2000s, volatility has increased, and since 2005 we have seen large increases in the price of fuel. Prior to 2005, DLA-E could stabilize prices because the Congress infused cash into the DWCF. However, since 2005, DLA-E has been unable to insulate the Services from fuel price changes. Because most fuel used by the Department is used for operational purposes, an unfunded fuel requirement may have an impact on operations.

While fuel purchases represent only about 2.5 percent of the Department's budget, large variation exists among the Services. In FY 2012, fuel accounted for almost 16 percent of Air Force O&M expenditures, but only 4 percent for the Army and 1 percent for the Marine Corps. Also, since 2004, the rate of increase in the fraction of the O&M budget that is attributable to energy costs implies that, as energy prices have increased, exposure to price risk has increased relative to other expenditures. We calculated this unbudgeted requirement to be about $27 billion dollars measured in constant FY 2013 dollars terms. Finally, we estimated that a 30 percent correction factor applied to the expected price of fuel over the period 2005–2011 would have reduced the unbudgeted requirement to less than $2 billion.

The organizational processes shaping how this unfunded requirement affects operations is explored in the remainder of this chapter.

B. Fuel Processes in the Services

Subsection A described how the Services are affected by fuel price volatility and price increases, but not how fuel prices affect readiness. Readiness is carefully monitored and regulated by Service higher headquarters, OSD, and the Congress, which means that many checks are in place to ensure that units drive the miles, steam the ships, and fly the hours required in order to be ready to defend the nation. The nature of these checks varies from Service to Service, and affects the means by which fuel prices have the potential to affect readiness. The remainder of this chapter will describe the process both in general and in Service-specific detail.

The basic fuel process is similar between Services. Each Service's costing office calculates the price per unit of activity—mile, hour, or steaming day—of fuel-consuming pacing items by multiplying the average consumption rate per unit of activity times the official OSD-published fuel rate. Another office determines the peacetime operational and training requirement for that activity based on historical activity levels, the Global

Force Management Allocation Plans (GFMAPs), and training models. The Service budget office then multiplies the price per unit of activity by the validated requirement for the activity, and submits the budget, which goes through the normal Program Objective Memorandum (POM) and budgeting process. DoD continues to update the amount programmed for fuel as OMB updates its fuel projection, until the budget is submitted to the president.

Once the budget has been signed into law, the budget offices monitor execution to varying degrees. If fuel prices go up, they calculate the unfunded requirement and search for a way to meet it, whether through reductions in fuel consumption, reprogramming, or requests for supplemental funds. The next several subsections will describe these processes in more detail.

1. Air Force

The Air Force programs for flying hours rather than for fuel directly. A3 determines the flying hour requirement for operational and training hours based on the GFMAPs and Combatant Commander (COCOM) requirements and the training requirement as determined by the Air Force Single Flying Hour Model. The Air Force has historically been unable to execute all training hour requirements because (1) crew availability has been limited due to operational requirements, (2) some training hours have been replaced with operational hours, and (3) unplanned events, such as the grounding of the F-22s, have occurred. Beginning in 2012, the Flying Hour Program (FHP) was optimized to account for the increase in operational hours for Operation Enduring Freedom (OEF). Practically speaking, this means that although the requirement for hours remains unchanged, the requirement is not fully resourced because it cannot be fully executed. Unfortunately, Air Force representatives say that the cut may have been too deep, and in 2012 money had to be reprogrammed to protect flying hours.

Independently of the hour requirement calculations, Secretary of the Air Force, Financial Management and Comptroller, Directorate of Cost Analysis (SAF/FMCC) calculates a fuel rate, or cost per barrel. This rate differs from the OSD fuel rate because the Air Force does not purchase all of its fuel from DLA. SAF/FMCC calculates a factor by which to multiply the OSD rate by taking the ratio of price paid at any moment to the DLA price at that moment, using the previous five years of consumption data. If the DLA price tended to be above market price, this factor would decrease the rate, and if the DLA price tended to be below market price, this factor would increase the rate, to enable the Air Force to continue to source its fuel where needed. This factor does not account for changes in DLA price from the budgeted price, and so does not insulate the Air Force from DLA price fluctuations.

SAF/FMCC then calculates the cost of a flying hour for each system. About 30 percent of this cost is made up of fuel. Most of the remainder of the cost is from

consumables and repair parts associated with aircraft maintenance, and the remainder is contracts and other support services. SAF/FM then takes the cost per hour and matches it to the validated requirement generated by A3 in order to create the budget. This cost includes all costs associated with the flying hour, not just fuel. The fuel portion of the cost is calculated by multiplying the fuel rate by the historical fuel consumption for the system. Operational and training consumption are calculated together, even though operational hours tend to be more fuel-efficient because the situations for which the crews train are more demanding than those that occur in everyday operations, especially given the nature of the threat in Central Command (CENTCOM). Changes in the ratio of training to operational hours, therefore, may result in under- or over-resourcing. This means that as DoD pivots to the Pacific—an Anti-Access Area Denial (A2AD) region—and draws down from operations in CENTCOM, the cost per flying hour may be higher than projected based on historical operations.

When there is a price increase, either mid-year or when the price at the start of the year exceeds the budgeted price, funds available for the required hours are insufficient. When this happens, SAF/FMCC calculates a new fuel rate and a new cost per hour. SAF/FMOO works in coordination with A3 to determine the resulting unfunded requirement, given execution so far, and updated expectations about the remainder of the fiscal year. If external circumstances caused under-execution of flying hours prior to the price change, or if circumstances have changed to reduce the number of hours the Major Commands (MAJCOMs) believe they can execute, the unfunded requirement decreases.

The Air Force then makes a corporate decision about whether to source any unfunded requirement. In recent history, the Air Force has purportedly always chosen to prioritize readiness, and to source the unfunded requirement by either requesting supplemental funding or by reprogramming. The Air Force has considered itself to have a readiness problem since at least the 1980s, meaning that it has been unable to adequately train sufficient numbers of pilots and crews in full-spectrum operations to meet its strategic demand. Except in special circumstances, this occurs because operational demands often prevent crews from flying all of their full-spectrum training hours. While operational hours provide useful experience, they are generally less demanding and often do not prepare pilots and crews for full-spectrum operations. Because other factors already prevent pilots and crews from receiving all the training they require, the Air Force leadership prioritizes the training hours they do have, and ensures that they receive funding for all the hours that can be executed. The Air Force views any further reductions in training hours as having a negative impact on readiness.

Until that corporate decision has been made and sources of funding are identified to meet the requirement, A3 coordinates with the MAJCOMs to determine how best to allocate the year's remaining resources. A single flying hour costs several times the cost of the fuel for that hour, so cutting one hour yields several hours' worth of fuel-specific

funds. Furthermore, not all hours cost the same, so fewer hours may need to be cut from one weapon system than another in order to meet the unbudgeted requirement. A3 works at a high level to ensure that strategic needs and readiness priorities are met, while the MAJCOMs work with the units to meet their needs and allocate hours appropriately. If the corporate decision to fund the unfunded fuel requirement were not made, then SAF/FMOO would use A3's resource allocation and adjust the budget accordingly. This occurred during sequestration, when the Department chose to stand down entire units rather than risk across-the-board readiness reductions, in order to ensure that the pilots they had remaining were fully ready.

The FHP is sufficiently large and executes at a sufficiently constant level that unbudgeted requirements due to fuel are usually not felt until the end of the year. This means that even though reprogramming actions generally do not provide funds until late in the fiscal year, flying hour execution can continue without having to move cash from other O&M accounts. This is critical because the FHP is too big to borrow from any other account, and is often a source of short-term cash for other O&M accounts.

It is difficult to trace the source of funds used for the unfunded fuel requirement because most reprogramming occurs as part of the omnibus reprogramming action, which lumps all bills and all bill payers without tying sources to consumers of specific reprogrammed funds. Preferred sources are the MILPERS (Military Personnel) account, due to understrength, and other under-executing programs. Investment accounts are less preferred, but common bill payers.

In recent history prior to FY 2013, the Air Force claims never to have reduced hours due to budgetary constraints. Prior to the FHP optimization in FY 2012, the Air Force was better equipped to absorb changes in fuel price, because it funded its full flying hour requirement without being able to fly so many hours. Operational demands often mean that pilots are unavailable to fully train for full-spectrum operations, resulting in decreased readiness. The optimization attempted to remove the redundantly programmed hours, but ended up removing too many. In FY 2012, the MAJCOMs found themselves without the funds to fly training hours for which pilots were available. A reprogramming action was initiated, and the MAJCOMs were told to fly to their maximum capacity and to expect reprogrammed funds at the end of the year. In the beginning of FY 2013, a similar problem occurred, and a similar decision was made, until sequestration took place and the Air Force was forced to ground entire squadrons. The optimization is budgeted in the current Future Years Defense Program (FYDP), with a steady ramp down as operational requirements in Afghanistan ramp down, so it is possible that in future years the Air Force may regain some of its ability to absorb fuel price changes. Chapter 4 will evaluate quantitatively whether the mechanisms in place to prevent detriments to readiness were effective.

2. Army

Unlike the Air Force, the Army does program for fuel. The distinction between the two approaches is subtle but important. Both use readiness requirements to determine required gallons and dollars for fuel during the POM build, but by wrapping fuel costs into flying hours and allocating those flying hours, the Air Force tells units exactly how much training they should do. If cuts must be made, entire hours are cut and allocated. If the cost per hour decreases, the units return any excess funds. But on the whole, units fly the hours they are given. In contrast, the Army creates readiness benchmarks and general training schedules, and then uses these readiness requirements to build the POM and allocate dollars. It is then up to commanders to use their resources to train their units to the set benchmarks. Lower echelon units are allocated gallons, and general training requirements are pre-determined, but miles and fuel usage are not. It is therefore up to a unit to determine how many miles it actually drives, and that unit is constrained by the resources that were provided to it. The unit commander has much more flexibility with regard to training. In fact, the Army Budget Office (ABO) does not even monitor fuel consumption directly; that is left up to the Army Major Commands (MACOMs) or echelons below.

G3 (Army, Operations and Plans) coordinates with the MACOMs to determine the operational fuel requirement. Peacetime operational fuel is primarily consumed by unit training, and is thus driven by OPTEMPO and the training schedules. Each training event has a number of pacing vehicle miles associated with it, according to historical usage. Those miles also have historical burn rates, which are used to determine the gallon requirements.

The requirements have not been fully funded in recent history. In part this is because of stresses related to the wars,[29] and in part because the Army can manage lower resourcing using the ARFORGEN cycle. Units closer to their deploy date receive preferential funding in order to prepare for their mission. As the wars draw down, the ARFORGEN model is being reassessed, and it is unclear what effects such a change will have on the relationship between fuel and readiness in the Army.

G3 works with the US Army Forces Command (FORSCOM) and the US Army Training and Doctrine Command (TRADOC) to determine appropriate resource allocation and passes the validated requirement on to ABO, which multiplies the requirement by the fuel rate to program for fuel. In the budget, fuel funds are allocated to the MACOMs in accordance with their validated requirements.

[29] Units have been so stressed due to the wars that there is not always enough time for all training events while in home station.

During the year of budget execution, ABO does not directly monitor fuel execution. Fuel funds are distributed across multiple Surface Action Groups (SAGs). These SAGs are monitored by ABO, but ABO does not have visibility with regard to fuel execution. This means that if the fuel price increases, tradeoffs must be made at the MACOM level or below, with limited oversight by Army Headquarters. At the headquarters level, there appear to be fewer mechanisms insulating readiness from fuel price fluctuations in the Army than in the Air Force. Conversely, there is a weaker connection between fuel execution and readiness in the Army than the Air Force, and fuel is a much smaller percentage of total Army O&M budget, which might make it easier for the Army to absorb without negatively affecting readiness. We do know that the number of gallons allocated to units at lower echelons changes in-year, and that units that exceed their allocation are audited, but without visibility into the processes at the MACOM and unit level, we do not know whether fuel reallocation is associated with fuel price changes, and cannot qualitatively assess whether fuel price volatility is likely to have an effect on readiness. Chapter 4 will use quantitative techniques to isolate the effect of fuel price changes on unit activity.

3. Navy

Like the Air Force, the Navy FHP programs and executes flying hours rather than fuel directly. Flying hours are closely monitored, and any cuts due to funding are made according to priority using the Flying Hour Resource Model (FHRM).

The surface fleet processes are somewhere in between the FHP's and the Army's. Fuel for the surface fleet is programmed directly, as in the Army, but its consumption is more rigidly monitored, as in the FHP. The forward projection of ships and groups is determined by the GFMAPs. This means that the basic framework around a ship's schedule is set and cannot be changed without changes in strategy. Parameters for ship speed and engine configuration under different conditions are also pre-determined. There is some flexibility within those rigid guidelines: commanders are incentivized, using monetary awards and recognition, to use as little fuel as possible, and have a limited amount of leeway with regard to the schedule. For example, within the parameters of a ship schedule as dictated by the GFMAP, and policies on engine configuration and ship speed for a given operating environment or mission, a ship may be able to operate with a more efficient engine configuration, or, weather permitting, may arrive early at port to allow the seamen to take shore leave.

The flying hour and ship steaming requirement is built into N43 (Naval Operations, Fleet Readiness). The Marine and Navy FHP flying hour requirements are built using training and operational requirements, and validated using the FHRM. The Navy costing office independently determines the cost per flying hour, which is input into the FHRM. A ship's steaming requirement is built using the schedule provided by the GFMAPs and

historical burn-rates of gallons per day for different classes of ship in different training stages. The training activity that must be completed during each stage is described in the *Surface Force Exercise Manual*.[30]

After N43 has built the requirement, N98 (Naval Operations, Air Warfare) validates both the requirement and the cost, using historical burn rates and cost per flying hour. N98 has a top line that it is allocated from higher headquarters, into which it incorporates the flying hour and fuel requirement. Historically, fuel requirements have tended to win out over other requirements. N98 passes its validated requirement upward to N9 (Naval Operations, Warfare Systems), which validates it against a higher top line and passes it upward again through N8 (Operational Navy, Integration of Capabilities and Resources). It is then passed through Financial Management and Budget, Integration (FMB-I) to the end of the POM process.

Once the Navy receives an appropriation from the Congress, obligation authority is handed down to the two fleet commands—Command, Pacific Fleet (COMPACFLT) and Forces Fleet Command (formerly COMLANTFLT)—which execute the funds separately. Fuel funds are monitored carefully throughout the budget year. Variation in fuel consumption is largely driven by weather—ships must steam to avoid storms, and aircraft fly when there are clear skies. A calmer than average month will mean less steaming and more flying, and a more stormy month will mean more steaming and less flying. Flying hours will vary, but pilots still have a minimum number of hours that they must fly per month, which limits the amount of possible variability. This natural variation impacts how easily the Navy can absorb fuel price increases. In a particularly stormy year, the fuel price increase might be all the more impactful. Given the variability, the fuel requirement for the remainder of the year is recalculated each month. If the fuel price increases and the new price times the new requirement exceeds what remains in the budget, an unfunded requirement results.

When an unfunded requirement arises, it is first up to the two fleets to identify available funds within the operations account to meet it, while attempting to preserve flying hours and to meet ship schedules. Little can be done in the flying hour program because the cost of a flying hour is fairly rigid—maintenance cannot be deferred due to safety issues.

There is more flexibility in the ship operating accounts. Maintenance could be deferred and fewer repair parts could be purchased. Unfortunately, deferring maintenance has a higher back end cost because repairs are often more expensive than preventive maintenance, and deferring maintenance can lead to more expensive repairs later and

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30 US Navy, *Surface Force Exercise Manual, COMNAVSURFPAC/COMNAVSURFLANT instruction 3500.11* (2012).

shorter ship life. Buying fewer repair parts also has a higher back end cost because if ships set off without the parts necessary to do underway repairs, using sunk labor, more work has to be done during depot maintenance, using contract labor. Both also have a potential impact on materiel readiness, because as ship systems fall into disrepair, casualty rates go up and the ship's ability to perform tasks on its METL is degraded. This means that limited amounts can be taken from ship parts accounts, but little else can be done at the lower echelons without failing to meet the GFMAPs or flying hour requirements.

Minor changes can also be made to the practical ship schedule. The presence schedule, which gives latest arrival dates, cannot be changed, so steaming can only change to a small degree. However, port visits can be cut, and time at destination can be reduced. While this does not have a direct effect on readiness, it does have an effect on crew morale, and decreases a ship's level of theater engagement. Changes might also be made to training events, although ships are still required to participate in certain events.

Finally, under dire constraints, ships can be forced to break regulation in one of two ways. This is far more likely to occur due to operational, rather than budgetary, constraints, but is nonetheless a possible mechanism for conserving fuel. Regulation dictates that ships must not go below 60 percent of their fuel capacity, so that in case of an emergency, the ship will not be dead in the water. Sixty percent is a minimum and can differ based on context. For example, when there is a hurricane nearby, ships are required to have a much higher fuel level should there be an unexpected delay in returning to port. Going below 60 percent would mean that a ship would need refueling less often en route, saving all the costs associated with the trip made by the refueler. Similarly, constraints on engine configuration could be relaxed, allowing ships to adjust their speed and engine configuration to optimize fuel consumption.[31]

If no excess funds are available without damaging readiness, the Navy budget office will attempt to find funds, either through a reprogramming action, or a supplemental request. Reprogramming would occur through the omnibus reprogramming request, in which bill payers are not directly linked to the bills they pay; however, the bulk of the reprogramming action comes from under-executing programs, procurement, and under-execution in the MILPERS account. If headquarters makes the decision to find funds, it communicates this to the fleets, which engage in cash flowing, or cash borrowing from other O&M accounts, to fund steaming and flying hours until the funds come through. If the Congress does not provide reprogramming authority or supplemental funds, reductions in hours and ship schedules must be made. Hours are reduced by priority using the FHRM.

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[31] Depending on the ship type and a variety of other variables, different speeds and engine configurations can be used to optimize fuel consumption.

According to lower echelon interviews with the fleets, they have always received funds from higher headquarters when fuel prices have increased, but have altered schedules, cut hours, and delayed maintenance and parts procurement when other budgetary constraints were imposed. If the fuel price change were severe enough, especially if it occurred at the same time as a constraint such as sequestration or continuing resolutions concurrent with policy changes, there is a clear mechanism by which readiness could be directly affected. This was of particular concern to Fleet Forces Command, which has been under severe enough non-fuel-related budget constraints that interviewees believe readiness might be affected if a fuel price increase were to compound current constraints. Whether readiness has been affected, and whether the mechanisms to prevent it have so far been effective, will be assessed in Chapter 4.

4. Conclusions

The Air Force and Naval Air Force both program for hours, rather than fuel, and have mechanisms in place to prioritize and control any reductions, thereby minimizing any effects on readiness. Furthermore, both Services closely monitor aircraft fuel at the headquarters level and prioritize readiness funding. Both Services report that they have prioritized readiness. Whether these mechanisms are effective at protecting readiness is explored in Chapter 4.

The Navy also closely monitors fuel for ships, and has mechanisms at the headquarters level to protect readiness. However, there is more flexibility in the accounts through which materiel readiness could be affected. Absent data, the present research does not analyze casualty reports or other indicators of materiel readiness. The following chapter discusses the effects of fuel price volatility on readiness as measured by ship steaming and fuel consumption, which captures the readiness of the Navy to meet presence and complete its missions and has been demonstrated to be a good proxy for materiel and training readiness.

The Army does not directly monitor fuel execution at the headquarters level. The effects of fuel price changes are managed by the MACOMs or lower echelons. Without visibility into the processes, there is no way to know qualitatively whether mechanisms exist to insulate Army readiness from fuel price increases, or whether such mechanisms are even necessary, given that fuel is only a small portion of Army O&M. We do know, however, that fuel execution is monitored at a lower echelon, and that unit fuel allocation can change over the course of the year. The following chapter quantitatively isolates the effects of fuel price volatility to explore whether fuel prices do affect activity, regardless of whether mechanisms exist.

4. Estimating the Relationship between Changes in Fuel Prices and Readiness

To estimate the effect of changes in fuel prices on readiness, we considered both the long-term effect (across budget years) and the short-term effect (within budget year). All of the data sources, system types, and names of systems analyzed for this paper are listed in Appendix A.

A. The Data

We obtained the data used to measure Army readiness from the US Army Operating and Support Management Information System (OSMIS), the core element of the US Army Visibility and Management of Operating and Support Costs (VAMOSC) program. The data cover activity levels (miles driven or hours flown) for seven aircraft systems, nine combat systems, and eighteen vehicle systems in four major commands observed quarterly from FY 2001 to FY 2011. OSMIS tracks this data for the Office of the Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE). Although the Defense Readiness Reporting System (DRRS) was considered as a source of direct Army readiness data (training activity, equipment on-hand levels, reported unit status etc.), the data available in the system were not conducive to further analysis. Sampling Army ground system miles over the available period, we see a general decrease over time in miles driven. Figure 6 shows this trend over time. Numbers on the y-axis represent miles per vehicle per year.

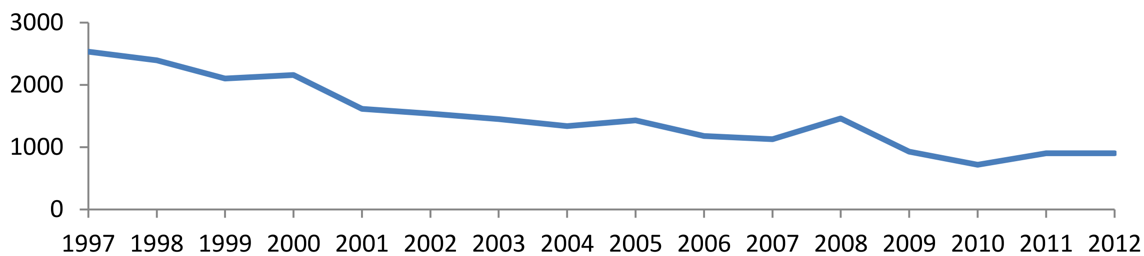

Figure 6. Trend in Army Ground System Miles from FY 1997 through FY 2011

Data on US Air Force aircraft are primarily from the REMIS (Reliability and Maintainability Information System) database. REMIS is an information system featuring a centralized record of Air Force system inventory, utilization, and maintenance data. This research includes relationships derived from several alternative readiness measures

including activity level (e.g., flying hours) and direct readiness (e.g., mission capability rates). Eleven aircraft systems sampled across different aircraft types in thirteen major commands are observed monthly from January 1993 to December 2012. The Air Force Total Ownership Cost (AFTOC) data system was also used to supply fuel consumption data as well as confirming REMIS activity levels on an annual basis. DRRS again was consulted and included direct readiness measures for mission capability and performance similar to those found in the REMIS database. Sampling aircraft flying hours over the available period, we see a general increase over time. Figure 7 shows this trend over time. Numbers on the y-axis represent flying hours per aircraft per year.

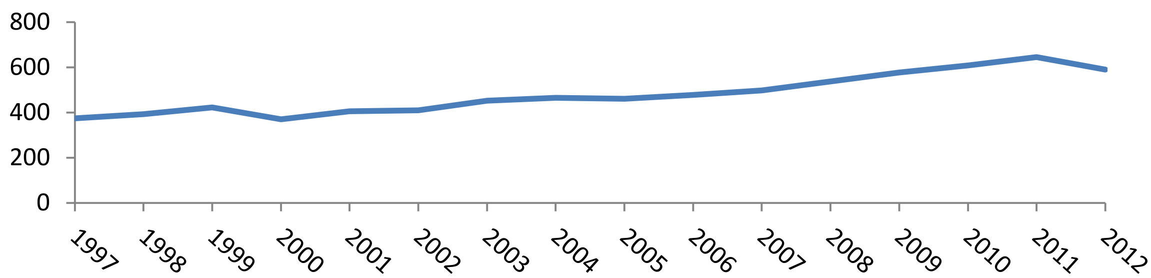

Figure 7. Trend in Air Force Aircraft Flying Hours from 1997 through 2012

Data on Navy ships are from the US Navy's VAMOSC program. The system includes activity (e.g., steaming hours), fuel consumption, and maintenance cost information. Data extracted for the following analysis include thirty-one ship classes observed annually from FY 1993 to FY 2011. Data on Navy aircraft are also from the US Navy VAMOSC system and include seventy-five aircraft systems observed annually from FY 1997 to FY 2011. Similar to the ship data, aircraft data include activity (e.g., flying hours), fuel consumption, and maintenance cost information. For both system classes, maintenance data is used as an indirect measure of readiness status. Unlike the US Army and US Air Force data sets, no US Navy data include observations on a less than annual frequency. No other US Navy data providers were available for this study. Although DRRS was consulted on readiness data, Navy data were not extracted from DRRS given that DRRS was perceived to provide limited modeling opportunity. Sampling Navy steaming hours over the available period, we see little change over time. Figure 8 shows this trend. Numbers on the y-axis represent steaming hours per ship per year. A tabular summary of the three Services' data sources follows in Table 3.

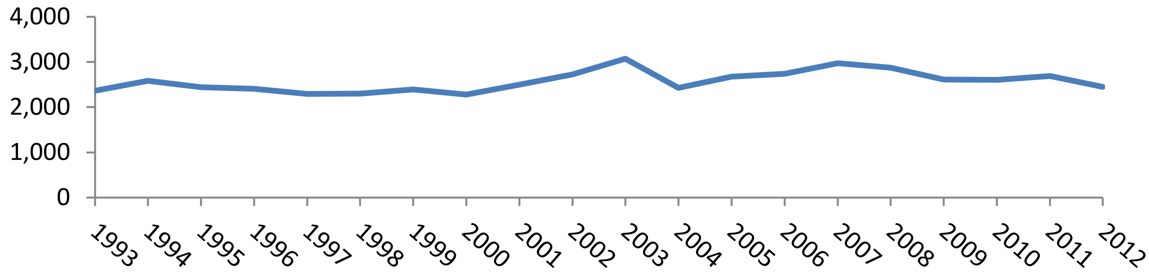

Figure 8. Trend in Navy Steaming Hours from FY 1993 through FY 2011

Table 3. Summary of Data Sources

System	Service	Source	Description
Aircraft, Ground	Army	Army OSMIS	Quarterly OPTEMPO—miles driven and hours flown—from 1993
Aircraft	Air Force	Air Force REMIS	Monthly flying hours and mission capability metrics from 1990
	Navy	Navy VAMOSC	Annual flying hours and fuel consumption from 1997
Ship	Navy	Navy VAMOSC	Annual steaming hours and fuel consumption from 1997

B. Measuring the Response to Changes in Fuel Prices across Budget Years: Long-term Price Elasticity

In order to determine the responsiveness of inter-year OPTEMPO to inter-year prices, we fit OPTEMPO data to the following regression equations:

$$\ln Optempo_{FY} = \alpha + \beta \ln P_{x,FY} + \gamma FY + \varepsilon_{FY} \tag{3}$$

Consider Equation 3 term by term. Here, $\ln Optempo_{FY}$ is the natural logarithm of reported activity levels in fiscal year FY. The variable $\ln P_{x,FY}$ is the natural logarithm of prices in that year. For completeness, we investigate the response with respect to both budgeted and DLA prices, so the subscript x serves as a placeholder to signify whether the price variable is the budgeted ($x = B$) or the DLA ($x = DLA$) price. The term FY is a linear time trend that controls for price-independent OPTEMPO changes over the sampled period. The parameter ε_{FY} is an error term, and the estimated regression parameters are symbolized as α, β, and γ. The coefficient α is an intercept parameter that improves model estimation, and γ represents average year-to-year increase (or decrease) in logarithmic OPTEMPO levels, while holding prices constant. The primary coefficient of interest is β, which measures the percentage change in OPTEMPO levels in response to a 1 percent change in prices. Therefore, β measures the long-run elasticity of OPTEMPO (our readiness measure) with respect to price.

1. Army Analysis

In order to avoid overlooking command-specific responses or system-specific responses, we separated the OPTEMPO data by both system and command and ran a separate regression for each of 106 individual system-command combinations. We first examine the responsiveness of Army OPTEMPO to budgeted prices. Table 4 summarizes the estimated long-run elasticities.

Table 4. Estimated Army Long-term Fuel Price Elasticity using Budgeted Price P_B

Sample	Observations	Mean β	Min β	Max β	% with $\beta < 0$	Mean *p*-value
All regressions	106	−4.02	−18.30	0.75	81	0.16
Regressions w/ *p*<.05	59	−5.62	−18.30	−0.74	100	0.01

For simplicity, we define statistically significant regressions to be those whose price-elasticity estimates have p-values less than 0.05, and we also provide statistics for this subset of regressions. The average p-value is included in order to provide insight on the statistical precision of the observed elasticities across all regressions. Out of the 106 individual Equation 3 regressions for the Army, over half of the system-command combinations exhibited a statistically significant inter-year response of OPTEMPO to budgeted prices in the absence of any non-temporal controls, well over the number expected due to random variation alone. Of those statistically significant regressions, the average estimated elasticity is -5.6. That is, for these 59 statistically significant regressions, a 1 percent increase in budgeted prices correlates with an average 5.6 percent decrease in OPTEMPO.

Note that we cannot say with confidence that these estimates are evidence for a causal effect of prices on OPTEMPO since most of the dramatic increases in fuel prices occurred during a condensed six-year period from FY 2005 to FY 2010. If other non-price events during these six years caused the Army to reduce average OPTEMPO, these regressions would falsely attribute the reduction in OPTEMPO to price increases.

As a robustness check, we also looked for an elastic response to DLA price, since it is the price actually paid by the Services. We replicate the above analysis replacing the budgeted price with the DLA price. The results of this analysis are summarized in Table 5.

Table 5. Estimated Army Long-term Fuel Price Elasticity using DLA price P_{DLA}

Sample	Observations	Mean β	Min β	Max β	% with $\beta < 0$	Mean *p*-value
All systems	106	-3.06	16.24	0.80	86	0.21
All systems with *p*<.05	45	-4.60	-16.24	0.71	96	0.02

We see that a large number of Equation 3 regressions, 45 out of 106, estimate statistically significant price elasticities. Like the Equation 3 results for budgeted prices, these results suggest that when controlling only for time, much of the Army OPTEMPO data appear responsive to DLA prices. The average elasticity of -4.6 (albeit with large variation around the mean) suggests a 4.6 percent reduction in system OPTEMPO correlating with a 1 percent increase in DLA prices. The average estimated response of Army OPTEMPO to the DLA price is slightly smaller than the average estimated response to the PB price. This is not surprising, given that the budget price is the price used when requirements are set.

2. Navy Analysis

For the Navy, we obtained system-specific activity data and consequently ran individual regressions for each system. We obtained sufficient data for 14 individual ship types and 31 individual aircraft types. For each system type we ran regressions according to Equation 3 with both budgeted and DLA prices. Table 6 presents these results.

Table 6. Estimated Navy Long-term Fuel Price Elasticity

Sample	Observations	Mean β	Min β	Max β	% with $\beta < 0$	Mean *p*-value
		Budget price, P_B				
All regressions	45	-0.09	-1.80	0.86	53	0.38
Regressions w/ *p*<.05	7	-0.22	-1.50	0.86	57	0.03
		DLA price, P_{DLA}				
All regressions	45	-0.01	-1.26	0.78	44	0.42
Regressions w/ *p*<.05	5	0.17	-0.42	0.38	20	0.02

Table 6 indicates an average elasticity of less than 0.1 percent with respect to either price variable, with the vast majority of the regressions having p-values greater than 0.05. On average, the estimated effect of prices on OPTEMPO is not only statistically insignificant, but also very small (and sometimes positive!). Hence, there is no evidence of a meaningful negative response from Navy activity to either budgeted or DLA prices.

In the case of Navy ships, we acquired fuel consumption data as well as data on steaming hours while not underway. We varied the dependent variable to inspect whether alternative measures are responsive to prices. The natural logarithms of the following variables were investigated: barrels consumed while underway (per ship), the ratio of barrels consumed underway to barrels consumed while not underway, and the number of hours underway to the number of hours while not underway. The results indicate a lack of correlation between the logarithm of these dependent variables and logarithmic prices (both budgeted and DLA), suggesting again that there is no evidence that Navy activity or fuel consumption declined in response to increases in fuel prices.

3. Air Force

We obtained Air Force OPTEMPO data for seventeen different aircraft types, and Equation 3 was applied to each. As with the Navy and Army, we investigated Equation 3 with both the budgeted price and the DLA price as price variable. The results are presented in Table 7.

Table 7. Estimated Air Force Long-term Fuel Price Elasticity

Sample	Observations	Mean β	Min β	Max β	% with $\beta < 0$	Mean *p*-value
Equation 3 with budget price, P_B						
All systems	17	-0.03	-0.71	0.57	47	0.28
All systems with *p*<.05	4	0.09	-0.71	0.55	25	0.02
Equation 3 with DLA price, P_{DLA}						
All systems	17	-0.03	-0.70	0.44	53	0.40
All systems with *p*<.05	2	-0.13	-0.70	0.44	50	0.03

As we saw in the Navy case, the elasticities are very small, indicating a fraction of a percentage change in system OPTEMPO in response to a 1 percent increase in prices. Furthermore, only a small number of the regressions are statistically significant. Thus, these results suggest that there is no meaningful response in Air Force activity to budgeted or DLA prices.[32]

[32] We also varied the dependent variable of Model 1 to examine the price responses of the logarithm of gallons of fuel consumed per Air Force aircraft. These results similarly failed to show a robust response to prices.

4. Conclusion

To summarize the inter-year regression results, we note that the Army OPTEMPO data suggest a large statistically significant response to both DLA prices and budgeted prices for many system-command combinations when we control only for time. However, when controlling for Army mission changes, the proportion of statistically significant regressions with respect to budgeted prices drops to less than 20 percent of all regressions. Additionally, only one regression remains statistically significant with respect to DLA prices when accounting for this price-independent change. This reduction in the number of statistically significant regressions as well as the large variation in the elasticity among the regressions suggests a lack of consistent price response in the Army.

The Navy and Air Force data do not evidence a response to either budgeted or DLA prices. The vast majority of the elasticity estimates were small and not statistically significant. Therefore, based upon the data available, Navy and Air Force readiness did not appear to be harmed by inter-year price changes.

C. Measuring the Response to Unbudgeted Price Changes within a Year: Short-term Effects

To estimate the short-term effect of fuel price volatility, we estimated the response of various readiness measures to $P_{DLA,t} - P_{B,t}$, where $P_{DLA,t}$ is the price of fuel the DLA charges to the Services at time t and $P_{B,t}$ is budgeted fuel price used to fund the Services for the fiscal year that contains time t. We estimated and examined the impact of short-term fuel price volatility separately for Army systems, Air Force systems, Navy ships, and Navy aircraft.

The full regression equation for the quarterly Army data is:

$$Readiness_{smt} = \beta_0 + \beta_1\left(P_{DLA,t} - P_{B,t}\right) + \beta_2 SystemQuantity_{smt} + \beta_3 t + \beta_4 t^2 + \gamma_2 I(2^{nd}\ Quarter)_t + \gamma_3 I(3^{rd} Quarter)_t + \gamma_4 I(4^{th} Quarter)_t + \xi_{sm} + \varepsilon_{smt}, \quad (4)$$

where $Readiness_{smt}$ represents the reported activity level (miles driven or hours flown) for system s in major command m in quarter t and $SystemQuantity_{smt}$ represents the number of vehicles or aircraft of system s reported to be in the possession of major command m in quarter t. $I(2^{nd}\ Quarter)_t$, $I(3^{rd} Quarter)_t$, and $I(4^{th} Quarter)_t$ are indicator variables that equal 1 when an observation falls in the indicated quarter and zero otherwise (quarter 1 is the omitted category).[33] β_0, β_1, β_2, β_3, β_4, γ_2, γ_3, and γ_4 are parameters to be estimated; ξ_{sm} is a system-major command fixed effect; and ε_{smt} is an error term. β_1 is the parameter of interest that captures the change in activity levels due to

[33] Quarter 1 includes October through December, Quarter 2 includes January through March, Quarter 3 includes April through June, and Quarter 4 includes July through September.

increases in the DLA price relative to the budget price, and is predicted to be negative if fuel price volatility has a negative impact on readiness. Equation 4 is estimated as a fixed-effects panel regression with cluster-robust standard errors. A separate regression is estimated for contingency operations, non-contingency operations, and combined activity levels for each system class (aircraft, combat, and vehicle). Estimates of β_1 are shown in Table 8; estimates of the entire regression for each subsample are provided in Appendix E.

Table 8. Effect of Short-term Fuel Price Volatility on Army Activity

Activity Type	Aircraft	Combat	Vehicles
Non-Contingency Activity	0.3	44.0	118.9
	0.2%	7.4%	0.6%
Contingency Activity	6.6+	14.4	-760.2*
	5.4%	3.0%	-5.9%
All Activity	-2.4	41.4	-2046.1**
	-0.8%	3.8%	-6.1%

Note: Percentages reflect the effect of a \$30 increase in $P_{DLA} - P_B$ at the mean level of activity (\$30 × $\beta_1/Average\ Activity$). $^+$, *, and ** represent statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

As Table 8 shows, there is neither statistically significant nor economically significant evidence of a decrease in activity levels for Army systems except in the case of Army vehicles driven as part of contingency operations. Given the priority that contingency operations likely have over training operations, the statistically significant negative coefficient found for vehicle contingency operations is likely to be the result of spurious correlation due to simultaneous changes in prices and OPTEMPO. Regardless, the magnitude of the estimated effect is small: only about a 6 percent decrease in the mean miles driven, given a \$30 increase in the DLA price over the budgeted price.

The full regression for the monthly Air Force REMIS data is:

$$Readiness_{smt} = \beta_0 + \beta_1\left(P_{DLA,t} - P_{B,t}\right) + \beta_2 t + \beta_3 t^2 + \beta_4 I(OEF/OIF)_t + \beta_5 t \times I(OEF/OIF)_t + \gamma_2 I(2^{nd}\ Quarter)_t + \gamma_3 I(3^{rd} Quarter)_t + \gamma_4 I(4^{th} Quarter)_t + \xi_{sm} + \varepsilon_{smt}, \quad (5)$$

where $Readiness_{smt}$ represents one of seven observed measures of readiness for system s in major command m in month t. $I(OEF/OIF)_t$ is an indicator variable that equals 1 when an observation falls in an OEF/Operation Iraqi Freedom (OIF) year (2001–2011) and zero otherwise. $I(2^{nd}\ Quarter)_t$, $I(3^{rd} Quarter)_t$, and $I(4^{th} Quarter)_t$ are indicator variables that equal 1 when an observation falls in the indicated quarter and zero otherwise (quarter 1 is the omitted category). As with the Army analysis, β_0, β_1, β_2, β_3,

β_4, β_5, γ_2, γ_3, and γ_4 are parameters to be estimated; ξ_{sm} is a system-major command fixed effect; and ε_{smt} is an error term. β_1 remains the parameter of interest that captures the change in the various readiness levels due to increases in the DLA price relative to the budget price. Equation 5 is estimated as a fixed-effects panel regression with cluster-robust standard errors. A separate regression is estimated for each of the Air Force readiness measures. The seven readiness measures, their predicted response to increased fuel prices, and their estimated response (β_1) are described in Table 9; estimates of all coefficients of each regression are reported in Appendix E.

Table 9. Air Force Measures of Readiness

Readiness Measure	Predicted Response to Increasing $P_{DLA} - P_B$	Estimated Response to Increasing $P_{DLA} - P_B$	
Flight hours per aircraft	Negative	-0.0020	-0.1%
Mission capable hours per aircraft	Negative	0.0739	0.4%
Fully mission capable hours per aircraft	Negative	0.0007*	3.7%
Partial mission capable hours per aircraft	Positive	-0.0006*	-9.1%
Non-mission capable hours per aircraft	Positive	-0.0001	-1.3%
Partial mission capable hours per mission capable hours	Positive	-0.0008*	-8.5%
Sorties flown per sorties scheduled	Negative	0.0109	7.1%

Note: Percentages reflect the effect of a $30 increase in $P_{DLA} - P_B$ at the mean level of readiness ($\$30 \times \beta_1 / average\ readiness$). * represents statistical significance at the 0.05 level.

Of the seven measures of readiness, flight hours per aircraft is the only metric with an estimated response to fuel prices in the same direction as the predicted effect; however, this effect is very small and not statistically significant. For the remaining readiness measures, the estimated effects are all opposite the effect we would expect to see if unbudgeted fuel prices had a detrimental effect on readiness. For example, Table 9 suggests that when the DLA price increases relative to the budgeted price, the Air Force has more (rather than less) fully mission capable hours. However, these results should be interpreted with caution. As with the Army results above, these estimated effects could be due to spurious correlation between increasing short-term volatility in FY 2005–FY 2010 and other non-price driven changes in Air Force activities during this period (e.g., the increased use of drones or changes in mission), and several of the estimates are not statistically significant. Regardless, these results are suggestive that there is no detrimental impact of short-term fuel price volatility on Air Force readiness.

The full regression for the annual data on Navy ships is:

$$Readiness_{st} = \beta_0 + \beta_1(P_{DLA,t} - P_{B,t}) + \beta_2 AverageShips_{st} + \beta_3 t + \beta_4 t^2 + \beta_5 I(OEF/OIF)_t + \beta_6 t \times I(OEF/OIF)_t + \xi_s + \varepsilon_{st}, \quad (6)$$

where $Readiness_{st}$ represents one of six observed measures of readiness for ship class s in year t. $I(OEF/OIF)_t$ is an indicator variable that equals 1 when an observation falls in an OEF/OIF year (2001–2011) and zero otherwise. $AverageShips_{st}$ is a control for the average number of Navy ships of class s in year t. As with the Army and Air Force analyses, β_0, β_1, β_2, β_3, β_4, β_5, and β_6 are parameters to be estimated; ξ_s is a system fixed effect; and ε_{st} is an error term. β_1 remains the parameter of interest that captures the change in the various readiness levels due to increases in the DLA price relative to the budget price. Equation 6 is estimated as a fixed-effects panel regression with cluster-robust standard errors. A separate regression is estimated for each of the Navy ships readiness measures. The six readiness measures, their predicted response to increased fuel prices, and their estimated response (β_1) are described in Table 10; estimates of all coefficients of each regression are reported in Appendix E.

Table 10. Navy Ships Measures of Readiness

Readiness Measure	Predicted Response to Increasing $P_{DLA} - P_B$	Estimated Response to Increasing $P_{DLA} - P_B$	
Hours Underway	Negative	24.7+	3.7%
Hours Not-Underway	Negative	4.1	1.5%
Hours Cold Iron	Negative	-12.6	-1.0%
Diesel Barrels Consumed Underway	Negative	993.6+	6.1%
Diesel Barrels Consumed Not-Underway	Negative	201.6**	10.8%
Maintenance Cost	Negative	-441,770.6	-9.4%

Note: Percentages reflect the effect of a $30 increase in $P_{DLA} - P_B$ at the mean level of readiness ($\$30 \times \beta_1 / average\ readiness$). + and ** represent statistical significance at the 0.10 and 0.01 levels, respectively.

Similar to the Air Force, only two of the six readiness measures for Navy ships have estimated responses to short-term volatility in the same direction as the predicted response. The first of these estimates—the effect of volatility on hours cold iron—is small and not statistically significant; the second, maintenance cost, is larger—up to a nine percent decrease in maintenance expenditures from a $30 increase in the DLA price relative to the budgeted price—but this estimated effect is not statistically significant either (i.e., the estimate may be a result of random noise in the data). There is weak evidence that diesel consumption and hours underway increase in years in which the

DLA fuel price is higher; however, as with the Army and Air Force results, these results should be interpreted with caution due to the possibility of spurious correlation.

The full regressions for the annual data on Navy aircraft are:

$$Readiness_{st} = \beta_0 + \beta_1\left(P_{DLA,t} - P_{B,t}\right) + \beta_2 t + \beta_3 t^2 + \beta_4 I(OEF/OIF)_t + \beta_5 t \times I(OEF/OIF)_t + \beta_6 AircraftNumber_{st} + \xi_s + \varepsilon_{st} \quad (7)$$

and

$$\frac{Readiness_{st}}{AircraftNumber_{st}} = \beta_0 + \beta_1\left(P_{DLA,t} - P_{B,t}\right) + \beta_2 t + \beta_3 t^2 + \beta_4 I(OEF/OIF)_t + \beta_5 t \times I(OEF/OIF)_t + \xi_s + \varepsilon_{st}, \quad (8)$$

where $Readiness_{st}$ represents either hours flown or barrels of fuel consumed by aircraft class s in year t. $I(OEF/OIF)_t$ is an indicator variable that equals 1 when an observation falls in an OEF/OIF year (2001–2011) and zero otherwise. $AircraftNumber$ is a control for the average number of Navy aircraft of class s in year t. As with the previous analyses, β_0, β_1, β_2, β_3, β_4, β_5, and β_6 are parameters to be estimated; ξ_s is a system fixed effect; and ε_{st} is an error term. β_1 remains the parameter of interest that captures the change in the various readiness levels due to increases in the DLA price relative to the budget price. Equations 7 and 8 are estimated as fixed-effects panel regressions with cluster-robust standard errors. A separate regression is estimated for each of the Navy aircraft readiness measures. These readiness measures, their predicted response to increased fuel prices, and their estimated response (β_1) are described in Table 11; estimates of all coefficients of each regression are reported in Appendix E.

Table 11. Navy Aircraft Measures of Readiness

Readiness Measure	Predicted Response to Increasing $P_{DLA} - P_B$	Estimated Response to Increasing $P_{DLA} - P_B$	
Total Hours Flown	Negative	2.6	0.3%
Total Barrels of Fuel Consumed	Negative	-337.3+	-4.8%
Hours Flown per Aircraft	Negative	0.45	3.0%
Barrels of Fuel Consumed per Aircraft	Negative	15.2	10.8%

Note: Percentages reflect the effect of a \$30 increase in $P_{DLA} - P_B$ at the mean level of readiness (\$30 × $\beta_1/average\ readiness$). + represents statistical significance at the 0.10 level.

Only one of the four readiness measures for Navy aircraft reported in Table 11 has an estimated response to short-term volatility in the same direction as the predicted response. This estimated effect is marginally statistically significant and relatively small—around a 5 percent decrease in average fuel consumption if the difference $P_{DLA} - P_B$ grows by \$30.

D. Summarizing the Empirical Findings

We found weak evidence that some Army systems decreased activity levels in response to long-term fuel price increases. We did not find any meaningful evidence that short-term spikes in the DLA price relative to the budgeted price caused detrimental impacts to readiness measures in the Army, Navy, or Air Force. Overall, we were unable to find any reliable empirical evidence to support claims that Department exposure to volatility in fuel prices since 2005 has negatively impacted readiness. The only possible effect was for long-term price changes in the Army. This is not surprising, given how carefully fuel is monitored in the Air Force and Navy. Overall, these conclusions are consistent with the insights provided by interviews with relevant parties in the Services regarding how they have dealt with unanticipated increases in fuel prices.

5. Conclusions

Since 2005, there have been a series of unprecedented spikes in fuel price that the DWCF has been unable to stabilize. This has resulted in a $27 billion unbudgeted requirement. In this paper, we explored the effects of that unbudgeted requirement on readiness. Results from the regressions suggest that activity did not decrease due to fuel price increases. There were no drops in the number of barrels purchased from DLA, and the Service representatives we spoke to suggested that they had never reduced OPTEMPO due to fuel prices. This is likely because (1) the Services usually received some supplemental funding to help mitigate fuel price increases, (2) they sought and generally received reprogramming authority to cover the rest, and (3) requirements tend to change over the course of the year. The Services budget for their ideal consumption, but real-world events sometimes prevent them from executing their full. Readiness has been and continues to be a high priority, and institutional mechanisms exist, at least in the Air Force and Navy, to protect readiness in the face of budgetary shortfalls.

The quantitative and qualitative results suggest that fuel price volatility has not affected OPTEMPO, and has had a minimum effect on readiness. Whether this pattern continues in the future depends on whether the mechanisms that enabled the Services to protect readiness remain sufficient. Since FY 2011, the Congress has not provided supplemental funds; whether or not this continues will affect the Services' ability to handle fuel price changes. The Services are also under increasingly heavy budget constraints due to sequestration and other factors, which may mean fewer funds will be available for reprogramming within the execution year.

Several factors might affect the Navy's ability to handle fuel price changes. For the Navy's Fleet Forces Command, budgetary constraints are already affecting its materiel readiness to the point that, without relief, its budget office expects to have to cut hours and steaming. Furthermore, the Navy already has a strong fuel-reduction initiative, which some, though certainly not all, would argue has or will soon plateau. If the Navy is already using as little fuel as possible to accomplish its mission given the technology of today, then unfunded fuel requirements could have a larger impact. Finally, the pivot to the Pacific also means more intense training flights, which means that costs per flying hour based on historical records will underestimate the fuel cost. The pivot also means a greater and more intense ship presence. Fuel price increases will compound the already tight operational budget situation.

As before, the Army remains largely an unknown. As the wars wind down, units will be able to complete much of the training that was foregone due to operational requirements, which will have to be funded out of the base budget. For the Army, this means an increased focus on maneuver warfare, rather than counter-insurgency, which might affect unit fuel consumption. The Army is also looking for alternatives to ARFORGEN, and there is no way to know how its new readiness cycle will affect its ability to preserve readiness when fuel prices change. However, fuel is a growing but still small portion of Army O&M, so it may be easier for the Army to absorb price changes without higher echelon coordination, as is required in the Air Force and Navy.

With the end of the wars, the Air Force will be able to complete more of its required training, so there are likely to be fewer excess flying hours which, prior to FY 2012, could be used to absorb increases in fuel costs. Furthermore, even though training and operational hours are budgeted with the same cost per flying hour, training actually expends more fuel. As operational hours are replaced with training hours, the Air Force may face unfunded fuel requirements even without price increases. The pivot to the Pacific will also mean more intense training and greater peacetime presence in the Pacific theater. Fuel funding is likely to be tight in the future, and unbudgeted fuel price increases will compound this.

These budgetary constraints do not necessarily equate to reductions in readiness. Historically, the Services have protected readiness from fuel price fluctuations, and many of these constraints are exacerbated exactly because readiness is such a high priority. With the pivot to the Pacific, that Navy and Air Force will want to train harder. With the end of the wars in Iraq and Afghanistan, the Army will revisit maneuver warfare. As long as reprogramming action continues to be granted, the Service headquarters will do their best to protect readiness. This authority is likely, because fuel price-related needs are transparent and have tended to be accepted by the Congress. However, the price of readiness relative to other Department needs is likely to continue to increase. The tradeoffs made may become larger. Fuel price volatility acts as a multiplier—a price increase matters a lot more when other factors are constraining a Service’s ability to reprogram, or when supplemental funds are unlikely to be forthcoming. What these tradeoffs have been, and what they might be, is an important question for further research. But for now, by understanding how the Services have preserved readiness in the past, it may be possible to stave off readiness impacts in the future.

Appendix A.
Data Sources

Service	Data Source	System Type	System
Army	OSMIS	Aircraft Systems	Apache
			Blackhawk
			Medical Blackhawk
			Chinook
			Kiowa
			Lakota
			Warrior
		Combat Systems	ACE
			APC
			AVLB
			Abrams
			Bradley
			M992
			MLRS
			Paladin
			SICPS
		Vehicle Systems	CUCV
			HEMTT
			HEMTT Tanker
			HEMTT Wrecker
			HET
			HMMWV
			HMMWV AMB
			HMMWV ECV
			Heavy HMMWV
			LMTV
			M915
			M916
			M917
			M939
			MTV

Service	Data Source	System Type	System
			MTV Wrecker
			PLS
			Stryker
		Major Commands	FORSCOM
			TRADOC
			USAR
			ARNG
Air Force	REMIS	Aircraft Systems	B-1
			B-52
			C-17
			E-3
			F-16
			KC-135
			MQ-1
			MQ-9
			T-38
			T-6
			T1
		Major Commands	ACC
			AET
			AFE
			AFR
			AMC
			ANG
			FMS
			GBS
			MTC
			NAP
			PAF
			SOC
			USN
	AFTOC		
Navy	VAMOSC	Ship Classes	Ammunition ship
			Amphibious assault ship (general purpose)
			Amphibious assault ship (helicopter)
			Amphibious assault ship (multi-purpose)
			Amphibious cargo ship

Service	Data Source	System Type	System
			Amphibious command ship
			Amphibious dock loading
			Amphibious landing ship
			Amphibious transport dock
			Auxiliary research submarine
			Combat store ship
			Combat support ship
			Destroyer
			Destroyer tender
			Guided missile cruiser
			Guided missile destroyer
			Guided missile frigate
			Littoral combat ship
			Mine countermeasures ship
			Minehunter coastal
			Miscellaneous command ship
			Multi-purpose aircraft carrier
			Oiler
			Patrol
			Coastal
			Repair ship
			Replenishment oiler
			Salvage and rescue ship
			Salvage ship
			Submarine rescue ship
			Submarine tender
		Aircraft types	A-29
			A-6
			AH-1
			AV-8
			C-130
			C-2
			C-20
			C-26
			C-37
			C-40
			C-9
			CH-46

Service	Data Source	System Type	System
			CH-53
			CT-39
			E-2
			E-6
			EA-18
			EA-3
			EA-6
			EC-130
			EP-3
			ES-3
			F-14
			F-16
			F-5
			F/A-18
			HH-1
			HH-3
			HH-46
			HH-60
			KA-6
			KC-130
			LC-130
			MH-53
			MH-60
			MQ-8
			MV-22
			P-3
			RC-12
			RH-53
			RP-3
			RQ-4
			S-3
			SH-2
			SH-3
			SH-60
			T-2
			T-34
			T-39
			T-44

Service	Data Source	System Type	System
			T-45
			T-6
			T/FA-18
			TA-4
			TAV-8
			TC-12
			TC-130
			TC-18
			TE-2
			TH-57
			TP-3
			UC-12
			UC-35
			UH-1
			UH-3
			UH-46
			UH-60
			UP-3
			US-3
			VH-3
			VH-60
			VP-3
			YSH-60

Appendix B.
Acknowledgment of Supporting Offices

We would like to extend our appreciation to the following offices, which supported this project through interviews and the provision of data. The views contained in this report do not necessarily represent the views of these organizations.

- Secretary of the Air Force/Financial Management and Budget Office, Integration (SAF/FMBOI)
- Secretary of the Air Force/Financial Management and Budget Office, Operations (SAF/FMBOO)
- Secretary of the Air Force/Financial Management Directorate of Cost Analysis (SAF/FMCC)
- Secretary of the Air Force/Installations Environment and Logistics, Energy (SAF/IEN)
- Air Force Operations Plans and Requirements (A3)
- Office of the Assistant Secretary of the Navy, Energy (OASN EI&E, ODASN Energy)
- COMPACFLT Budget Office
- Pacific Fleet Flying Hour Program
- Navy Financial Management and Comptroller, Naval Operations, Integration of Capabilities and Resources, Fiscal Management Directorate (FM&C, FMB1b/N821)
- Naval Operations, Air Warfare (N98), Naval Operations, Energy and Environmental Readiness (N45)
- Naval Operations, Ship Ops and Flying Hour Program (N43)
- Forces Fleet Command
- Naval Sea Systems Command (NAVSEA)05
- ABO
- G3
- Army Cost & Economics (CE)
- OSD Comptroller

Appendix C.
DLA Energy Petroleum Product Purchases

DLA's fuel procurement includes bulk petroleum (JP-8, JP-5 and Diesel fuel), ship's bunker fuel, into-plan (refueling at commercial airports), and post camps-and-stations.[1] Table C-1 presents a summary of DLA fuel purchases by volume and costs from FY 2000 through FY 2012. Total purchases peaked at 145.1 million barrels in FY 2003 in the second year of OEF. JP-8 (the military version of JA-1—the kerosene turbine fuel adopted by international commercial aviation) is the largest category of fuel. Purchases of JP-8 peaked in FY 2004 and have fallen every year since.

1 Andrews, "Department of Defense Fuel Spending," 19.

Table C-1. DLA Energy Petroleum Product Purchases by Category (Millions of Barrels per Year)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Alt. Jet	1.0	1.4	0.7	0.1	0.2	8.7	11.4	5.4	9.3	15.6	19.4	23.1	25.8	29.7	29.7
JP-5	17.9	16.0	16.7	15.4	18.6	20.6	17.9	16.1	12.8	14.4	13.6	12.1	13.6	12.9	12.6
JP-8	60.1	61.2	68.6	61.7	62.3	73.4	72.2	74.7	71.3	71.3	68.2	62.5	57.6	54.7	49.5
Jet Total	**79.0**	**78.6**	**85.9**	**77.3**	**81.0**	**102.8**	**101.5**	**96.1**	**93.5**	**101.3**	**101.2**	**97.7**	**97.1**	**97.3**	**91.8**
Diesel and Distillates	16.9	16.5	16.1	15.5	17.6	19.3	25.2	21.0	21.2	22.1	22.8	24.5	212.2	19.2	20.9
AVGAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasohol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.4
Lube Oils	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Motor Gasoline, Leaded and Unleaded	0.6	0.5	0.5	0.6	0.9	1.3	1.5	0.7	2.1	2.0	1.9	2.0	1.9	1.7	1.4
Residuals	0.2	0.1	0.3	0.2	0.5	0.2	1.6	1.3	0.9	0.7	0.4	0.6	0.4	0.3	0.4
Subtotals	**96.7**	**95.8**	**102.8**	**93.7**	**100.0**	**123.6**	**129.9**	**119.2**	**117.7**	**126.2**	**126.4**	**124.9**	**120.7**	**118.8**	**114.9**
TF-RIO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Into-Plane	3.7	3.3	3.7	3.4	3.8	4.1	4.8	5.1	4.3	3.8	4.3	4.5	4.7	5.6	5.6
PC&S Category	4.7	3.8	3.7	4.3	4.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bunkers	2.6	2.6	2.5	2.7	2.5	2.3	8.0	8.3	6.7	4.1	3.8	3.4	3.1	2.2	2.1
Local Purchase	N/A	N/A	N/A	N/A	N/A	1.6	2.5	2.2	2.0	1.7	1.5	2.1	3.0	5.4	7.8
Purchased Barrels of Petroleum	**107.8**	**105.5**	**112.8**	**104.1**	**111.0**	**134.6**	**145.1**	**144.8**	**130.7**	**135.9**	**136.1**	**134.9**	**131.6**	**132.0**	**130.5**

Source: Anthony Andrews, "Department of Defense Fuel Spending, Supply, Acquisition, and Policy," Congressional Research Service, September 22, 2009, Table 1.

Appendix D.
Estimation of a *Post-hoc* “Optimal” President’s Budget Price

Given perfect hindsight, what would have been the DoD’s best policy to pursue over the 2005–2011 period if its sole objective had been to incur neither a deficit nor a surplus? Or, put another way, what adjustment to the PB price (P_B) would have resulted in the smallest absolute difference between the average annual DLA price (P_{DLA}) and P_B over the most volatile years? In algebraic terms, the “optimal” adjustment calculation can be expressed as:

$$Minimum\ Absolute\ Price\ Deviation = \min_{\delta} \sum_{2005}^{2011} |P_{DLA} - \delta P_B|, \tag{9}$$

where P_{DLA} is the weighted average standard price per barrel and P_B is the PB price per barrel in each fiscal year. δ is the policy adjustment factor. We estimate this by transforming the minimization problem into a linear programming formulation and solving.

The linear programming formulation after the transformation is:

$$min \sum_{i=2005}^{2011} (B_i^- + B_i^+) \tag{10}$$

subject to:

$$P_{DLA} - \delta P_B + B_i^- - B_i^+ = 0 \text{ for all } i = 2005, \ldots, 2011, \tag{11}$$

$$B_i^-, B_i^+ \geq 0 \text{ for all } i = 2005, \ldots, 2011, \text{ and} \tag{12}$$

$$\delta \geq 0, \tag{13}$$

where B_i^+ is a surplus variable, B_i^- is a slack variable; the objective function (10) is the absolute price deviation; (11) and (12) are a constraint set of balance equations; and (13) is a non-negativity constraint.

The solution to the linear programming problem is $\delta = 1.30$. That is, the best single-factor adjustment policy DoD could have pursued was to take the PB price and increase it by 30 percent every year from 2005 to 2011. This would have reduced the unfunded requirement total over this period from about \$27 billion to about \$2 billion (deficit) measured in constant FY 2013 dollars terms.

Appendix E.
Regression Tables

This appendix includes the full regression tables referenced in Chapter 4, Section 4.B.

Table E-1. Effect of Short-term Fuel Price Volatility on Army Non-Contingency Activity (Full Results)

	Aircraft	Combat	Vehicle
$P_{DLA} - P_B$	0.293	43.970	118.885
	(3.73)	(32.75)	(202.03)
System Quantity	41.186***	35.943*	559.257***
	(5.05)	(16.40)	(40.46)
$I(2^{nd}\ Quarter)_t$	-481.277***	-784.975	-106,510.307***
	(102.82)	(1,388.29)	(30,632.25)
$I(3^{rd}\ Quarter)_t$	675.789**	2667.829+	63,584.886*
	(215.71)	(1,538.41)	(24,599.85)
$I(4^{th}\ Quarter)_t$	791.296+	3076.734+	93,411.002+
	(405.88)	(1625.94)	(52983.00)
t	24.259	-453.341*	-1,630.664
	(16.35)	(172.84)	(1252.30)
t^2	-1.320	29.514**	-444.974**
	(0.78)	(10.05)	(141.60)
Constant	1,160.257**	-1,408.349	-76,571.436+
	(408.42)	(6607.84)	(40836.01)
R-sq (within)	0.555	0.383	0.743
R-sq (between)	0.892	0.180	0.937
R-sq (overall)	0.769	0.264	0.872
Obs	829	1,138	3,049

Note: Cluster-robust standard errors are reported in parentheses. +, *, **, and *** represent significance at the 0.10, 0.05, 0.01, and 0.001 levels, respectively.

Table E-2. Effect of Short-term Fuel Price Volatility on Army Contingency Activity (Full Results)

	Aircraft	Combat	Vehicle
$P_{DLA} - P_B$	6.560^{+}	14.413	-760.221*
	(3.40)	(35.55)	(376.38)
System Quantity	69.340***	89.065*	877.315***
	(5.43)	(34.23)	(137.17)
$I(2^{nd}\ Quarter)_t$	-418.429^{+}	-798.466	-17,911.019
	(237.89)	(712.91)	(10,825.21)
$I(3^{rd}\ Quarter)_t$	117.658	1,477.399	79,394.127***
	(92.95)	(1,222.40)	(21,188.09)
$I(4^{th}\ Quarter)_t$	236.051^{+}	1354.847	86,632.544***
	(128.26)	(1,053.71)	(23,284.12)
t	49.692*	-332.511	-9,217.031***
	(22.87)	(202.82)	(2,565.79)
t^2	-1.634	-21.225	-380.878^{+}
	(1.15)	(12.83)	(193.56)
Constant	754.634*	3,798.849	-111,823.685
	(293.39)	(5,272.35)	(111,421.20)
R-sq (within)	0.596	0.202	0.650
R-sq (between)	0.953	0.732	0.926
R-sq (overall)	0.838	0.455	0.764
Obs	829	1,138	3,049

Note: Cluster-robust standard errors are reported in parentheses. +, *, and *** represent significance at the 0.10, 0.05, and 0.001 levels, respectively.

Table E-3. Effect of Short-term Fuel Price Volatility on Army Combined Non-Contingency and Contingency Activity (Full Results)

	Aircraft	Combat	Vehicle
$P_{DLA} - P_B$	-2.419	41.390	-2,046.109**
	(4.92)	(58.28)	(761.57)
System Quantity	43.301***	27.578*	694.725***
	(11.07)	(10.49)	(82.03)
$I(2^{nd}\ Quarter)_t$	-939.568**	-2,115.788	-137,996.566**
	(287.32)	(1732.57)	(40945.38)
$I(3^{rd}\ Quarter)_t$	639.793*	3,072.841	121,056.284**
	(274.86)	(2182.50)	(36275.81)
$I(4^{th}\ Quarter)_t$	942.114*	3,568.918	160,726.501*
	(443.81)	(2,117.71)	(64,551.97)
t	106.795*	-676.890*	-6,160.279*
	(39.95)	(270.94)	(2,389.71)
t^2	-5.245*	-10.514	-1,298.441***
	(2.44)	(13.02)	(351.62)
Constant	3,463.185*	18,450.170***	-144,566.063
	(1,592.95)	(4,876.94)	(118,630.33)
R-sq (within)	0.265	0.148	0.590
R-sq (between)	0.921	0.227	0.920
R-sq (overall)	0.783	0.196	0.818
Obs	829	1,138	3,049

Note: Cluster-robust standard errors are reported in parentheses. *, **, and *** represent significance at the 0.05, 0.01, and 0.001 levels, respectively.

Table E-4. Effect of Short-term Fuel Price Volatility on Air Force Readiness Measures (Full Results)

	Flight hours per aircraft	Mission capable hours per aircraft	Fully mission capable hours per aircraft	Partial mission capable hours per aircraft	Non-mission capable hours per aircraft	Partial mission capable hours per mission capable hours	Sorties flown per sorties scheduled
$P_{DLA,t} - P_{B,t}$	-0.002	0.0739	0.0007*	-0.0006*	-0.0001	-0.0008*	0.0109
	(0.02)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
$I(2^{nd}\ Quarter)_t$	1.8551	-9.1761**	0.0047	-0.0027	-0.002	-0.0023	5.1100^{+}
	(1.25)	(2.89)	(0.01)	(0.01)	(0.00)	(0.01)	(2.81)
$I(3^{rd}\ Quarter)_t$	4.6425***	2.5499	0.0129^{+}	-0.0009	-0.0120***	-0.0042	4.0670*
	(0.91)	(2.37)	(0.01)	(0.01)	(0.00)	(0.01)	(1.86)
$I(4^{th}\ Quarter)_t$	3.7908**	0.4043	0	0.0005	-0.0005	0.0013	7.0837^{+}
	(1.29)	(2.94)	(0.00)	(0.00)	(0.00)	(0.00)	(3.79)
t	-0.7768	1.6566	0.0034	-0.0011	-0.0023	-0.0041	-0.6652
	(0.92)	(1.96)	(0.01)	(0.01)	(0.00)	(0.01)	(0.71)
t^2	0.001	-0.0027	0	0	0	0	0
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$I(OEF/OIF)_t$	132.30	-609.78*	-2.2485**	1.4101^{+}	0.8383*	2.3107*	-336.73*
	(101.95)	(255.30)	(0.73)	(0.73)	(0.35)	(0.92)	(128.28)
$t \times I(OEF/OIF)_t$	-0.2851	1.2820*	0.0047**	-0.0030^{+}	-0.0018*	-0.0049*	0.7017*
	(0.21)	(0.52)	(0.00)	(0.00)	(0.00)	(0.00)	(0.27)
Constant	76.842	1,047.23***	2.8579***	-1.4323*	-0.4256	-1.8757*	469.84^{+}
	(96.39)	(198.53)	(0.67)	(0.63)	(0.27)	(0.86)	(236.14)
R-sq (within)	0.01	0.028	0.08	0.058	0.029	0.064	0.021
R-sq (between)	0.002	0.064	0.002	0.017	0.061	0.03	0.576
R-sq (overall)	0.011	0.003	0.034	0.027	0.003	0.033	0.045
Obs	6,609	6,609	6,609	6,609	6,609	6,562	3,659

Note: Cluster-robust standard errors are reported in parentheses. +, *, **, and *** represent significance at the 0.10, 0.05, 0.01, and 0.001 levels, respectively.

Table E-5. Effect of Short-term Fuel Price Volatility on Navy Ship Readiness (Full Results)

	Hours Underway	Hours Not Underway	Hours Cold Iron	Diesel Barrels Consumed Underway	Diesel Barrels Consumed Not Underway	Maintenance Cost
$P_{DLA,t} - P_{B,t}$	24.7^{+}	4.08	-12.6	994^{+}	205**	-441,770.6
	(13.8)	(5.36)	(14.3)	(549)	(64.3)	(296,715.6)
Average Ships	2931.76***	928.17***	4929.32***	70,920.45***	5456.40***	1.39e+07***
	(148.24)	(134.92)	(59.41)	(4,313.11)	(523.24)	(3,332,521)
t	214,616.1*	-115,749.5	-74,389.04	1,032,014	151,197.2	-5.46e+09
	(93,225.59)	(147,311.8)	(110,346.2)	(4,958,350)	(596,865.2)	(4.42e+09)
t^2	-53.8*	28.9	18.8	-258	-38.1	1.40e+06
	(23.4)	(36.9)	(27.7)	(1.2e+03)	(149)	(1.1e+06)
$I(OEF/OIF)_t$	-2,641,239*	727,526.8	1,856,390^{+}	1.96e+07	551,856.7	5.16e+09
	(1,085,311)	(1,246,246)	(1,093,078)	(5.26e+07)	(5,798,331)	(5.62e+10)
$t \times I(OEF/OIF)_t$	1,322.0*	-364.7	-928.3+	-9,726.7	-279.6	-2,578,529.6
	(543.6)	(623.0)	(546.6)	(26,292.5)	(2,897.7)	(2.8e+07)
Constant	-2.1e+08*	1.20e+08	7.40e+07	-1.00e+09	-1.50e+08	5.50e+12
	(9.3e+07)	(1.5e+08)	(1.1e+08)	(5.0e+09)	(6.0e+08)	(4.4e+12)
R-sq (within)	0.928	0.731	0.964	0.85	0.684	0.439
R-sq (between)	0.982	0.924	0.991	0.741	0.497	0.592
R-sq (overall)	0.97	0.898	0.986	0.759	0.532	0.544
Obs	431	431	431	431	431	319

Note: Cluster-robust standard errors are reported in parentheses. $^{+}$, *, **, and *** represent significance at the 0.10, 0.05, 0.01, and 0.001 levels, respectively.

Table E-6. Effect of Short-term Fuel Price Volatility on Navy Aircraft Readiness (Full Results)

	Total Flying Hours	Total Barrels of Fuel Consumed	Flight Hours per Aircraft	Barrels of Fuel Consumed per Aircraft
$P_{DLA,t} - P_{B,t}$	2.61	-337.3^{+}	0.454	15.2
	(8.26)	(202.0)	(1.06)	(32.8)
Average Ships	313.2***	8.80E+03		
	(43.8)	(6.5e+03)		
t	292,662.8	3.26e+07^{+}	13,556.73^{+}	746,163.2**
	(188,260.3)	(1.68e+07)	(7,887.409)	(263,865.4)
t^2	-73.31	-8164.22^{+}	-3.40^{+}	-186.65**
	(47.11)	(4193.56)	(1.97)	(66.01)
$I(OEF/OIF)_t$	-3,107,559^{+}	-2.68e+08^{+}	-138666.4*	-5930566**
	(1,859,296)	(1.39e+08)	(61,535.56)	(2,051,137)
$t \times I(OEF/OIF)_t$	1,553.566^{+}	134,144.6^{+}	69.316*	2,965.12**
	(929.30)	(69,264.44)	(30.75)	(1,025.13)
Constant	-2.90e+08	-3.3e+10^{+}	-1.4e+07^{+}	-7.5e+08**
	(1.9e+08)	(1.7e+10)	(7.9e+06)	(2.6e+08)
R-sq (within)	0.928	0.731	0.964	0.85
R-sq (between)	0.982	0.924	0.991	0.741
R-sq (overall)	0.97	0.898	0.986	0.759
Obs	431	431	431	431

Note: Cluster-robust standard errors are reported in parentheses. +, *, and ** represent significance at the 0.10, 0.05, and 0.01 levels, respectively.

Illustrations

Figures

Tables

References

Alquist, Ron, Lutz Kilian, and Robert J. Vigfusson. "Forecasting the Price of Oil." *Handbook of Economic Forecasting* 2A (2013): 427–507. Accessed January 7, 2014. doi: 10.1016/B978-0-444-53683-9.00008-6.

Andrews, Anthony. "Department of Defense Fuel Spending, Supply, Acquisition, and Policy." Washington, DC: Congressional Research Service, September 22, 2009.

Defense Working Capital Fund, Department of Defense Study on Revolving Funds Operational Cash Balances. Report to the House Armed Services Committee. Washington, DC, January 2012.

DoD's Report on Operational Energy Budget Certification for Fiscal Year 2013: "Energy Investments for Military Operations." Accessed May 1, 2013. http://energy.defense.gov/Portals/25/Documents/Reports/20120815_FY13_OE_Budget_Cert_Report.pdf.

GAO report 10-592, "Military Readiness, The Navy Needs to Reassess Its Metrics and Assumptions for Ship Crewing Requirements and Training." Washington, DC: Government Accountability Office, 2010.

GAO report 12-887, "Military Readiness: Navy Needs to Assess Risks to Its Strategy to Improve Ship Readiness." Washington, DC: Government Accountability Office, 2012. Accessed April 28, 2013. http://www.gao.gov/ products/GAO-12-887.

GAO report 07-688R, "Defense Budget: Review of DOD's Report on Budgeting for Fuel Cost Fluctuations." Washington, DC: Government Accountability Office, 2007.

Goldberg, Lawrence. "Estimation of the Effects of A Ship's Steaming on The Failure Rate of its Equipment: An Application of Econometric Analysis." Professional Paper PP-280. Alexandria, VA: CNA, 1980. Accessed May 12, 2013. http://www.cna.org /sites/default/files/research/5500028000.pdf.

Nolen, Thomas D. "Isolation of Important Input Factors in the Performance of Operational Propulsion Plant Exams (OPPE) and Light Off Exams (LOE) for Atlantic Fleet Ships." Monterey, CA: Naval Postgraduate School, 1989. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA219807.

Schwartz, Moshe, Katherine Blakeley, and Ronald O'Rourke. "Department of Defense Energy Initiatives: Background and Issues for Congress." Congressional Research Service, December 10, 2012. Accessed May 1, 2013. http://www.fas.org/sgp/crs /natsec/R42558.pdf.

US Army *Counterinsurgency Field Manual*, FM3-24.

US Navy. *Surface Force Exercise Manual. COMNAVSURFPAC/COMNAVSURFLANT instruction 3500.11*. 2012.

Abbreviations

A2AD	Anti-Access Area Denial
A3	Air Force Operations Plans and Requirements
ABO	Army Budget Office
AFTOC	Air Force Total Ownership Cost
AHB	Assault Helicopter Battalion
ARFORGEN	Army Force Generation
BMC	Basic Mission Capable
CAB	Combat Aviation Brigade
CE	Cost and Economics
CENTCOM	Central Command
CMR	Combat Mission Ready
COCOM	Combatant Commander
COMPACFLT	Command, Pacific Fleet
CONUS	Continental United States
DASA-CE	Office of the Deputy Assistant Secretary of the Army for Cost and Economics
DLA	Defense Logistics Agency
DLA-E	Defense Logistics Agency-Energy
DoD	Department of Defense
DRRS	Defense Readiness Reporting System
DWCF	Defense Working Capital Fund
EIA	U.S. Energy Information Agency
FHP	Flying Hour Program
FHRM	Flying Hour Resource Model
FM&C	Financial Management and Comptroller
FMB-I	Financial Management and Budget, Integration
FORSCOM	United States Army Forces Command
FSRM	Facilities Sustainment, Restoration, and Modernization
FY	Fiscal Year
FYDP	Future Years Defense Program
G3	Army, Operations and Plans

GAO	Government Accountability Office
GFMAP	Global Force Management Allocation Plan
HBCT	Heavy Brigade Combat Team
IDA	Institute for Defense Analyses
IDIQ	Indefinite Delivery/Indefinite Quantity
LOE	Light Off Exam
LPG	Liquefied Propane Gas
MACOM	Army Major Command
MAJCOM	Air Force Major Command
METL	Mission Essential Task List
MILPERS	Military Personnel
MRAP	Mine Resistant Ambush Protected
N43	Naval Operations, Ship Ops and Flying Hour Program
N45	Naval Operations, Energy and Environmental Readiness
N8	Naval Operations, Integration of Capabilities and Resources
N9	Naval Operations, Warfare Systems
N98	Naval Operations, Air Warfare
NAVSEA	Naval Sea Systems Command
OASN EI&E ODASN	Office of the Assistant Secretary of the Navy, Energy
O&M	Operations and Maintenance
OCO	Overseas Contingency Operations
OCONUS	Outside the Continental United States
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OMB	Office of Management and Budget
OPPE	Operational Propulsion Plant Exam
OPTEMPO	Operating Tempo
OSD	Office of the Secretary of Defense
OSMIS	US Army (Operating and Support Management Information System)
PESTO	Personnel, Equipping, Supply, Training, and Ordinance
POM	Program Objective Memorandum
REMIS	Reliability and Maintainability Information System
SAF/FM	Secretary of the Air Force, Financial Management

SAF/FMBOO	Secretary of the Air Force/Financial Management and Budget Office, Operations
SAF/FMBOI	Secretary of the Air Force/Financial Management and Budget Office, Integration
SAF/FMCC	Secretary of the Air Force/Financial Management Directorate of Cost Analysis
SAF/IEN	Secretary of the Air Force/Installations Environment and Logistics, Energy
SAG	Surface Action Group
SBCT	Stryker Brigade Combat Team
TRADOC	United States Army Training and Doctrine Command
VAMOSC	US Army Visibility and Management of Operating and Support Costs
WTI	West Texas Intermediate

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14. ABSTRACT
The objective of this task is to determine the extent to which fuel price volatility has driven The Department of Defense (DoD)'s unfunded requirements and to what extent that, in turn, has affected military readiness. The results of our research indicate that price volatility caused unbudgeted fuel requirements totaling approximately $27 billion from Fiscal Year (FY) 2005 through FY 2011, the last year we examined. However, we found no significant evidence during this period that in-year unbudgeted fuel price changes caused reductions in readiness. We did find weak evidence that the Services may have scaled back a few future operations in response to long-term price increases, but because readiness is a high priority, money was always located to meet programmed requirements in the current year. Finally, we investigated the question: given perfect hindsight, what funding scheme would have minimized the unbudgeted requirements that were experienced? Using linear programming, we estimated that the best policy DoD could have pursued was to take the President's Budget fuel price and increase it by 30 percent every year from 2005 to 2011. Such a policy would have resulted in a net unbudgeted requirement of only $2 billion dollars measured in FY 2013 dollars, down from the $27 billion dollar shortfall that we actually observed.

15. SUBJECT TERMS
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